Study on household wastewater characterization and septic tanks' function in urban areas of Vietnam(Dissertation_全文)

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
COD_{Cr}	Chemical oxygen demand determined by Dichromate potassium
DUT	Danang University of Technology
GDP	Gross domestic product
GNI	Gross National Income
GSGES	Graduate School of Global Environmental Studies
HH	Household
HUST	Hanoi University of Science and Technology
IESE	Institute of Environmental Science and Engineering
INEST	School of Environmental Science and Technology of HUST
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme by WHO and UNICEF
O&M	Operation and maintenance
OSS	On-site sanitation
Septage	The combination of sludge, scum, and liquid in a septic tank
SS	Suspended solids
ST	Septic tank
TKN	Total Kjeldahl Nitrogen
TP	Total phosphorus
UNDP	United Nations Development Programme
UNICEF	United Nations Children’s Fund
URENCO	Urban Environment Limited Company Ltd.
VND	Vietnamese Dong
VSS	Volatile suspended solids
WB	World Bank
WHO	World Health Organization

EXECUTIVE SUMMARY

It has been well known that coverage of sewerage systems is very limited in developing countries. Due to this limitation, a large amount of wastewater from households is discharged into open water areas causing water pollution and public health risk. The situation becomes seriously as septic tanks, the most on-site treatment facilities, are not properly managed. The septic tanks receive solely toilet waste and are not regularly desludged. The non-regular desludging is a major reason to diminish these tanks' performance. As long as sewerage systems have not been completely developed, proper management of the septic tanks is essential to enhance the tanks' performance; thus, to reduce pollution loading. This study is aimed at characterizing wastewater at household level, and then evaluating septic tanks' function by case studies in urban areas of Vietnam.

Characteristics of water consumption and discharge of urban residents

Differently from residential water consumption in developed cities, water consumption in developing cities varies widely due to a dynamic situation caused by rapid urbanization and development. These processes result in the on-going change of residential lifestyles. Nuclear households (two-generation households) become popular instead of multigenerational households and elderly people tend to live further away from their children. It may affect to water consumption and discharge patterns due to a generational gap of water-related behaviors.

Average daily-per-capita water consumption was calculated based on water consumption amount measured by tap water meter mentioned in water bills. The water bills were collected through a structured interview in urban areas of Hanoi. It showed that average daily-per-capita water consumption was 146±58 L/day. We also found that per-capita consumption amount in the households with elderly people was significantly lower than that in the households without the elderly ($p < 0.001$). Although household size is negatively correlated to per-capita consumption amount in several studies in developed countries, such a clear trend was not observed in this study even though the household sizes were widely distributed in the target households. Hourly water consumption and water-consuming activities were investigated for ten households in modern apartment within 48 hours. It showed two distinct peaks, morning and evening peaks corresponded to before and after working/schooling hours. Per-capita water consumption in morning session (4-10 AM), day time session (10 AM-5 PM) and evening session (5-11 PM) accounted for 18.7%, 19.6% and 57% of total consumption within a day, respectively. Bathing/showering and laundry, happened mostly in the evening, were found to be highly correlated to water consumption. Toilet flush happened throughout a day and contributed about 20% to total water consumption.

Concentration patterns of at-source household wastewater were investigated for five households located nearby a canal. Wastewater concentration showed its variations within a day and peaked at 3-4 PM. Since toilet use was the major water-consuming activity and water consumption was low at this time period, septic tank effluent released by toilet flush was not diluted, and then remained highly concentrated. The concentrations then dramatically decreased at 6-7 PM due to the dilution caused by a sharply increase in water consumption. Although no activity was recorded at late night, the wastewater remained in plumbing system was stilled gradually released. Average concentrations of COD_{Cr}, BOD_5, TKN, T-P and SS of at-source wastewater were 474 mg/L, 225 mg/L, 57 mg/L, 8 mg/L, and 80 mg/L, respectively. These results can be fundamental data for the comprehensive understanding of household water consumption and discharge characteristics of urban residents.

Household pollution loading and evaluation of septic tanks' function

Similarly to other developing cities, septic tank is the main system for toilet waste pre-treatment. Wastewater, including greywater and septic tank effluent from urban households, is discharged directly into rivers and canals. In addition to previous survey on household water consumption and discharge, we conducted a river survey at an inlet and outlet of To Lich river where the wastewater is discharged into. The river survey was consisted of hourly flow measurement and six-hour interval water quality analysis within 48 hours.

The results showed that the household pollution loadings from the households were highest during 10 AM-4 PM, which might come from septic tank effluent due to high frequent use of toilets. Unit pollution loadings of COD_{Cr}, BOD_5, TKN, T-P and SS from household wastewater were 65.6 g/cap/day, 31.9 g/cap/day, 7.6 g/cap/day, 1.1 g/cap/day and 11.6 g/cap/day, respectively.

The households in the watershed contributed about 22% (130,247 m^3/day) to discharge amount into the river (603,738 m^3/day). The flow-rate at the outlet of the river was less fluctuated than at the inlet as the wastewater at upstream needed 31 hours for running to the outlet. The households contributed a large proportion of organic pollution to the river. The estimated COD_{Cr} and BOD_5 loadings were 58.5 ton/day and 28.4 ton/day, comprising about 53.5% and 47.0% of those loadings from the watershed, respectively. The loadings of TKN (6.8 ton/day) and TP (1.0 ton/day) from household wastewater contributed 24.5% and 40.0% to those loadings in the river, respectively. Although TP in household wastewater contained a large part of solid matter which settled after discharge from households, it was still the big contributor to TP loading in the river. These data provide more detailed understanding of contribution of household wastewater to water pollution in Hanoi where almost wastewater is discharged into open water areas.

Septic tank pollution loads and accumulated sludge characteristics

The septic tanks play an important role to treat toilet waste before discharging to open water areas, but non-desludging diminishes the tanks' performance. Previous study investigated frequent desludging as a measure for provisional-and-urgent sanitary improvement by recovery septic tanks' performance. Pollution loads from septic tanks was estimated, and then sludge accumulation was characterized based on a case study in Lai Xa hamlet, Kim Chung commune, Hoai Duc district, a sub-urban area of Hanoi.

A structured interview was conducted for 100 households in the hamlet. A drainage watershed, composed of 62 households, was selected to study pollution loads from septic tanks. Total number of septic tanks was 46, of which 21 tanks were located inside the target watershed. We sampled septic tanks' effluents, measured bottom sludge accumulation, and sampled septage.

The results showed that septic tank effluent had a high variation. Pollution loads from septic tanks were then calculated as 12.0 g/cap/day for COD_{Cr}, 7.0 g/cap/day for BOD_5, and 2.0 g/cap/day for SS, which can be understood that the septic tanks have an important role to control pollution loads from households.

Sludge accumulation rate was obtained by measuring sludge depth inside the tank by specific instruments. The length and width of the septic tanks were collected from a structured interview. Accumulation rate of bottom sludge was 0.04±0.05 L/cap/day, which was lower than other referenced data. Characteristics of septage showed that organic matter was mainly in solid form and settling function would play a crucial role for pollutant removal in septic tanks. The data are important for a proper design of a septic tank and to adequate estimation of desludging frequency for a better septic tank management.

Effects of septic tank management on septage composition

Septic tanks' conditions are various because of different O&M by users. The tanks' performance affects septage composition and this effect should be investigated for technology selection to treat septage. The effects of septic tank management on septage composition were investigated in urban areas of Danang. Thirty-six households called for desludging service were visited for a structured interview. Twenty septage samples out of the 36 households were obtained. The interview included information about household attributions, septic tank structure and O&M (*e.g.*, septic tank size, number of users, desludging intervals). Composite sampling was implemented while a vacuum truck was discharging septage into treatment plant to obtain a representative sample for each septic tank.

Urban residents in Danang use cistern-flush toilets and pour-flush toilets, and then the flushed excreta go to septic tanks soaked into underground. The results indicated that collected septage was well buffered with alkalinity was 2,163 mg/L and 2,208 mg/L for septage in septic tanks connected to cistern-flush toilets and pour-flush toilets, respectively. The BOD_5 represented about 30% of the COD_{Cr} for both septage, indicating that the septage was stabilized but could still be further biodegraded. High nutrient contents in the septage might become an incentive to achieve environmentally-friendly treatment by hygienic recovering for crop fields.

Correlations between specific desludging intervals (month•person/m^3) and the Cl^- adjusted concentrations of COD_{Cr}, BOD_5, and SS were investigated. It indicated that when the specific desludging intervals increased, an increase in the concentrations of COD_{Cr} (R^2=0.68), BOD_5 (R^2=0.57), and SS (R^2=0.72) were also found. If household size and septic tank volume are fixed, a longer operating period could provide higher septage concentrations due to excessive solid accumulation. Therefore, septage treatment design needs to be based on desludging strategy.

Social acceptance of septage-oriented compost

Three-fourth of Vietnamese population is doing agricultural activities. Therefore, composting, an environmentally-friendly treatment of septage, can be a suitable option for septage treatment. The residents, as the food consumers, have a certain concern for health safety if septage-oriented compost is applied for agriculture. The structured interviews throughout the whole research (n=100 in urban areas of Hanoi, n=100 in sub-urban areas of Hanoi, and n=36 for urban areas of Danang) collected information about respondents' knowledge of septic tank and septage management, and whether they accept septage-oriented compost.

Almost of the respondents did not know the role of frequent desludging. Few households responded that desludging makes septic tanks hygienic. Most questioned residents, even the households whose septic tanks were desludged did not know to which the collected septage was transported. They only concerned that the septage is pumped out of their septic tanks.

A large number of interviewed households accepted septage-oriented compost (more than 80%) while a small number of them concerned about hygiene of compost products.

They were worried about pathogens in the compost made from septage. Some households said if compost made from hygienically treated septage, they are willing to accept.

Since Vietnam is agricultural country, composting is favorable solution to recycle nutrients in septage into crop fields. However, health safety in terms of heavy metals and pathogens should be considered.

Chapter 1 Introduction

1.1 Sanitation

1.1.1 Global burdens of water and sanitation-related diseases

Poor water quality and inappropriate sanitation pose a major threat to human health. It was stated in Target 7C of the Millennium Development Goals that the number of people without access to safe drinking water and basic sanitation should be halved by 2015 as compared to 1990 when 1.2 billion and 2.7 billion people had no access to water supply and sanitation, respectively. As of 2012, over 2 billion people have gained access to improved sources of drinking water, and almost 2 billion people gained access to improved sanitation. However, more than 700 million and 2.5 billion people still lack the access to adequate water and sanitation, respectively. Remarkably, although open defecation decreased from 24 percent to 14 percent globally between 1990 and 2012, it is still practiced by 1 billion people (WHO/UNICEF, 2014).

Diseases caused by inadequate sanitation are a burden to global population especially those in low- and middle-income countries. Diarrhoreal illness was stated as the second rank caused by the lack of sanitation services after Bilharzis (Wright, 1997). Annually, there are two million diarrheal deaths related to unsafe water, sanitation, and hygiene and the vast majority comes from under five year-old children. However, diarrhoreal disease risk can be reduced thanks to adequate water supply and sanitation (Fewtrell *et al.*, 2005).

1.1.2 Sanitation facilities

A technical distribution of the global sanitation facilities is shown in **Figure 1-1**. Sewage system is one of the major sanitation facilities in developed countries but the system requires a huge expense and decades-long construction for its development (UNEP-IETC, 2002). Therefore, many urban areas in developing countries are suffering from the delay of sewerage infrastructure development (ADB, 2001). As long as conventional sewerage has not developed, low cost sewerage options is a suitable choice (Foster, 2001; USEPA, 2000). However, it will take some decades to establish sewerage for the urban areas of developing countries, except big city centers. Until sewerage system will be completely developed, a complementary system to sewerage may be required to address urgent sanitation issues in developing countries in conjunction with sewerage development.

In urban areas of developing countries, onsite sanitation (OSS) systems are popular (**Table 1-1**). OSS includes non-sewered household, public toilets, aqua privies and septic tanks (Strauss *et al*., 2003). In Bangkok and Manila, 65% and 78% of inhabitants are linked to OSS. The ratios are highly in the Philippines.

Among OSS, the septic tank is most popular on-site treatment facility for developing countries but the population using septic tanks is not clear. It is recognized that most septic tanks in developing countries are not properly managed (ADB, 2000). Because the main function of septic tanks is settling, the system do not produce high quality effluent. Most septic tanks in developed countries are connected with trench fields for effluent treatment, while septic tanks in developing countries are built without such trench fields. Moreover, septic tanks in most developing countries have not been regularly desludged, and the overflow often carries out sludge inside septic tank. Excessive sludge accumulation occupied settling volume; thus, reduce septic tank performance. The septic tanks are often desludged when blockage or nuisance happens. A large proportion of the population relies on OSS and therefore on fecal sludge management. However, most fecal sludge management is unplanned and provided by informal sectors. If desludging is conducted, collected septage is not treated properly (Strauss *et al*., 2003) in spite of the fact that desludging and septage treatment are essential for proper management of septic tanks.

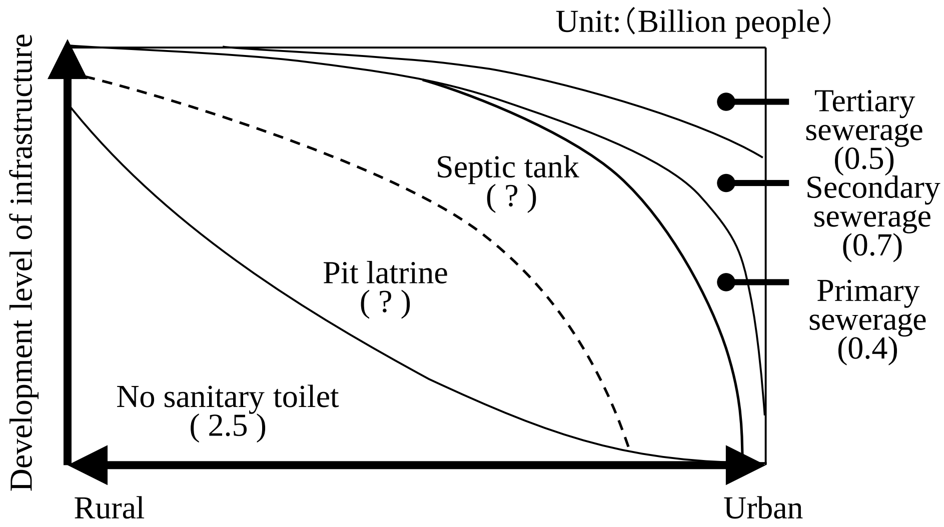

Figure 1-1 Technical distribution of global sanitation facilities (billion people). This figure was illustrated by Harada (2007) based on the data from OECD (2002)

Table 1-1 Proportion of urban populations served by on-site sanitation systems (OSS) (Strauss *et al*., 2003)

City or country	Proportion of inhabitants served by on-site sanitation system
Ghana	85
Bamako (Mali)	98
Tanzania	> 85
Manila	78
Philippines (towns)	98
Bangkok	65
Latin America	> 50

1.2 Domestic wastewater management in urban areas in developing countries

It is estimated that global wastewater production is about 1,500 km^3 per day (UN, 2003) of which more than 80 percent is not collected or treated (Corcoran *et al*., 2010). The ratio is significantly high in developing countries where a huge volume of untreated wastewater is dumped directly into water resources. For example, a population of 9 million people in Jakarta generates 1.3 million cubic meters of wastewater each day, of which less than three percent reaches treatment plant. On the other hand, with a population of four million, 1.2 million cubic meters of urban wastewater generated is treated per day in Sydney. Each person in Sydney produced nearly triple as much wastewater as a person in Jakarta (Corcoran *et al*., 2010). Untreated wastewater containing organic materials, nutrients, toxic substances and pathogens deteriorates water quality and threatens public health. Moreover, wastewater is widely used as a source of irrigation water in developing countries. About 10 percent of total irrigated land in developing countries is using wastewater for irrigation. WHO-FAO (2006) estimated that 10 percent of the world population relies on food grown with contaminated wastewater. The wastewater reuse has raised a concern about safety for food production.

Since global population is rapidly increasing and the major growth will take place in urban areas of developing countries, the increased wastewater production must be given attention to protect water resources and public health. Centralized wastewater treatment system requires huge investment, operation and maintenance cost, as well as technical expertise. For developing countries, this system will not be developed in near future. Instead, improvement of current situation, including proper management of septic tanks is urgent to urban wastewater management.

1.3 Purpose

The overall objective of the research is to study household wastewater and septic tanks' function in urban areas of developing countries based on a case study in Vietnam.

1. To study the characteristics of water use and discharge of urban residents in developing countries.

2. To study pollution from household wastewater and evaluate septic tanks' function.

3. To study septic tank pollution loads and characterize accumulated sludge inside septic tanks.

4. To evaluate the effect of septic tank management on septage composition.

5. To study social acceptance to compost made from septage.

Introduction

- Introduction to this dissertation (Chapter 1).
- Overview of urban sanitation in Vietnam: The sanitation-related information of Vietnam, Hanoi, and Danang are summarized primarily focusing on septic tank management (Chapter 2).

Household wastewater

- The study of household water consumption and discharge in urban areas of Hanoi: a relation between residential lifestyles and water consumption and discharge is analyzed as a typical context of developing countries. To examine the relation, frequencies of water consuming activities were recorded to explain hourly water consumption and wastewater concentration patterns (Chapter 3).

- The study of pollution loads from household wastewater and evaluation of septic tanks' function based on a watershed in an urban areas of Hanoi: pollution loads from household wastewater are estimated in comparison with pollution loads accumulated in a river, where the wastewater is discharged into. Septic tanks' function in wastewater treatment at household level is also evaluated (Chapter 4).

Septic tank

- The study of septic tank pollution loads and sludge characteristics based on a target watershed in a sub-urban area of Hanoi: Greywater and septic tank effluent are discharged into a drainage canal. Pollution loads from septic tanks are estimated from septic tank effluents and are compared with pollution loads which are estimated from measured data at the outlet of the watershed. Accumulation rate of bottom sludge inside the septic tanks are calculated and septage characteristics are investigated (Chapter 5).

- The study of a relation between septic tank management and septage composition: Effects of non-desludging intervals on septage composition is analyzed based on the data collected in the survey in Danang (Chapter 6).
- The study of social acceptance to septage-oriented compost: Public knowledge on septic tank management and the acceptance to compost made from septage (Chapter 7).

Conclusions and recommendations

- Conclusions of this thesis and recommendations (Chapter 8).

Structure of the dissertation is shown in **Figure 1-2**.

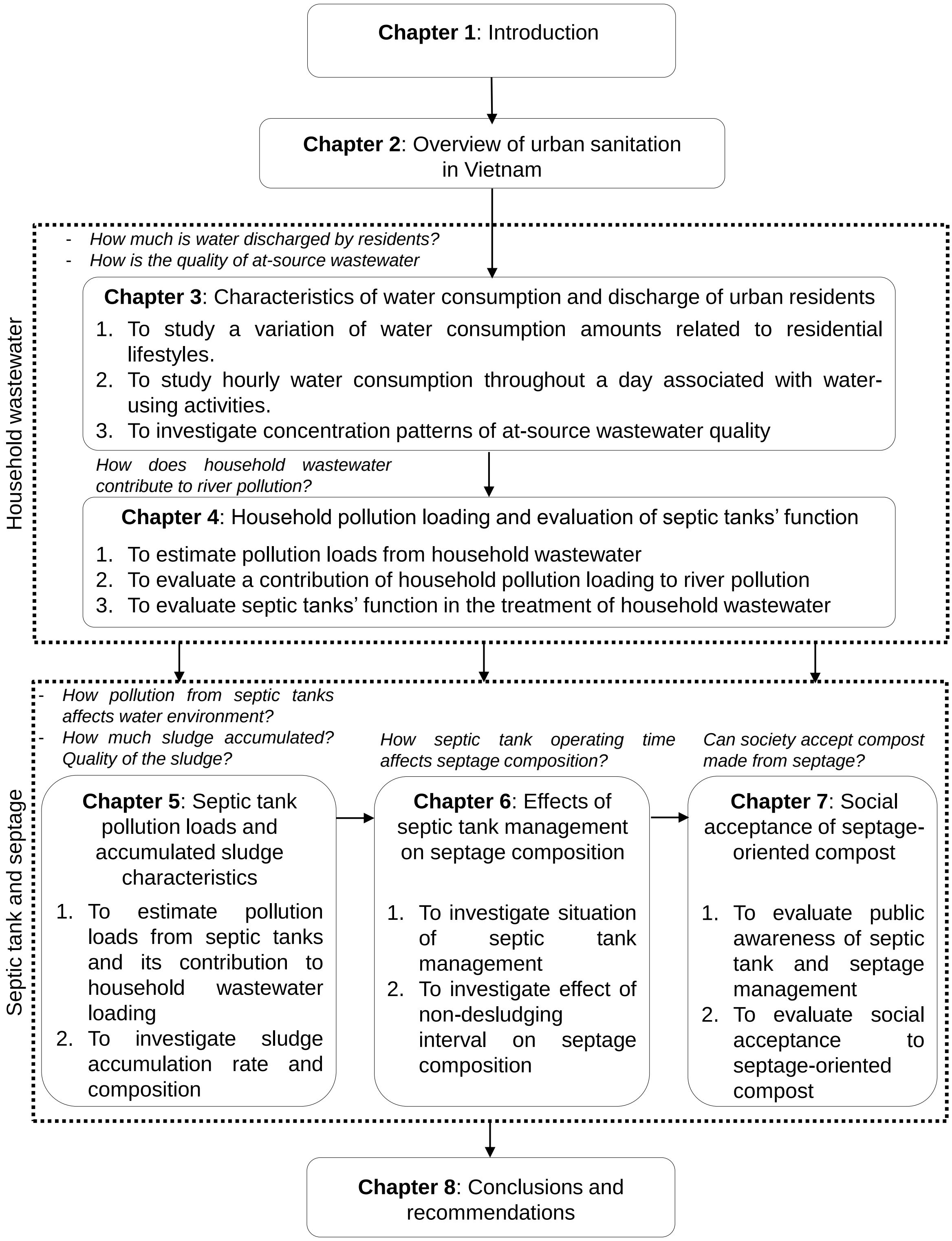

Figure 1-2 Framework of the research

1.4 The internship and surveys in Vietnam

The Graduate School of Global Environmental Studies, Kyoto University offers students an internship program in the Environmental Management course, which requires at least five months in doctoral courses in the graduate school. The author completed a five-month-internship and other four months for data collection related to the research. The total time length was composed of one month in Japan to study sludge treatment technology and eight months in Vietnam to conduct surveys for the Ph.D. research. Schedules and contents of all internships are listed in **Table 1-2**.

The first internship was conducted in Danang University of Technology (*i.e.*, DUT), Danang, Vietnam in March of 2012. In this internship, the author conducted a survey on septic tank management and septage composition in urban areas of the city. After the internship, effect of septic tank management on septage composition was realized.

The second internship was at Aqua Clean Sanagawa, a sludge treatment plant in Toyokawa, Aichi prefecture run by KUBOTA Environmental Service Co. Ltd. (KUBOTA) from September of 2012 to October of 2012. In this internship, the author studied sludge treatment technology and participated in the activities of KUBOTA, comprising of a study on improvement of deodorizing system and treatment efficiency and treatment plant maintenance.

The internships and sampling in Hanoi lasted for seven months. The author conducted surveys in an urban and sub-urban areas of Hanoi to investigate household water consumption and discharge characteristics, septic tank and septage management, and septic tank pollution loads.

Table 1-2 Schedule of internships and surveys

Schedule	Content	Host institute
March 1st - 24th 2012	Septic tank management and septage composition in Danang, Vietnam	DUT
September 10th - October 5th 2012	Japanese sludge treatment technology	KUBOTA
December 5th 2012 - January 30th 2013	Water consumption and discharge characteristics in Hanoi, Vietnam	INEST
August 2nd - September 29th 2013	Water consumption characteristics in Hanoi, Vietnam	INEST
November 2nd - 26th 2013	Septic tank pollution loads in Hanoi, Vietnam	INEST
December 31st 2013 - January 30th 2014	Septic tank pollution loads in Hanoi, Vietnam	INEST

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Chapter 2 Overview of urban sanitation in Vietnam

2.1 General description of Vietnam

Vietnam is the easternmost country on the Indochina Peninsula in Southeast Asia. The country is bordered by China to the North, Laos and Cambodia to the West, the Gulf of Thailand in the Southwest, and the South China Sea to the East and South (**Figure 2-1**). The country is divided into 64 provinces including the capital Hanoi. The total area of the country is 331,052 km^2 (**Table 2-1**). About 25 percent of the total land area is covered by plains, the most important being the Bac Bo in the North and Nam Bo in the South, corresponding to the courses of the Red river and Mekong river, respectively (FAO, 2011). The total population in 2012 was around 88.7 million, which is 13th most populous country in the world. Although urbanization is growing rapidly, only 32% of total population was living in urban areas.

With rapid economic growth and urbanization, Vietnam has improved income level and now is ranked in lower middle income with a GNI of 1,550 US$ per capita per year as of 2012. In recent years, Vietnam has experienced moderate economic growth, at approximately 5.5% per annum. The country has a dense network of 2,360 rivers with a length of more than 10 km each. There are 16 river basins that are larger than 2,000 km^2, half of which have a catchment area larger than 10,000 km^2. The largest basins are the Mekong and

Figure 2-1 A map of Vietnam (CIA, 2011)

the Red river/Thai Binh, covering 45% of the territory (FAO, 2011).

Table 2-1 General information of Vietnam

Item	
Area (km^2)	330,951
Total population (GSO, 2012)	88,772,900
Rural population (GSO, 2012)	60,416,500
Urban populations (GSO, 2012)	28,356,400
GDP (billion current US$) (WB, 2012)	$155.8
GNI per capita, Atlas method (current US$ per capita per year) (WB, 2012)	$1,150
Increase in access to water sources from 1990 to 2010 (WHO/UNICEF, 2010)	57% to 95%
Increase in sanitation access from 1990 to 2010 (WHO/UNICEF, 2010)	37% to 76%

2.2 Sanitation in Vietnam

2.2.1 Water use and sanitation access in Vietnam

The total annual water withdrawal for agriculture, industries, and municipal purposes was estimated 82.3 km^3 in 2005, of which only 1.5% accounted for municipal sectors (**Figure 2-2**). In the same year data, surface water was the major withdrawal (98.1%), while groundwater withdrawal made up 1.40 km^3 (1.7%). Ground water is mainly used for municipal water supply in urban areas.

Water and sanitation sector in Viet Nam has achieved significant progress in both physical infrastructure, legal and institutional terms, with considerable support from not just government but especially development partners. The water and sanitation sector in Vietnam lacks mechanisms for regular sector assessment that addresses critical issues such as the different institutional, managerial and operational aspects of the sector and its links to health, well-being and economic development (WSP, 2012). Combined sewer systems with overflow chambers are the most common wastewater collection systems in urban Vietnam.

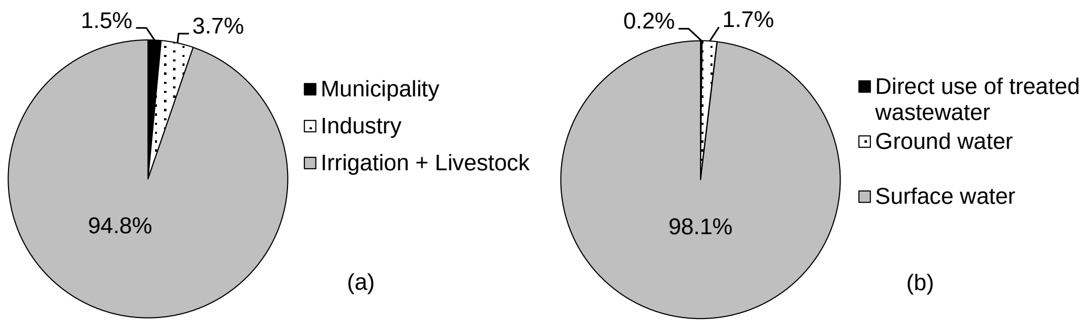

Figure 2-2 Water withdrawal by sector (a) and by source (b) (FAO, 2011)

Up to 1,000 communes in Vietnam's Red River and Mekong Delta regions are facing high risks of arsenic-contained water sources. Vietnam has 180 processing and industrial zones, 12,259 healthcare facilities, 72,012 enterprises, which discharge hundreds of untreated wastewater cubic meters into its rivers a day. Up to 80% of diseases in Vietnam are caused by polluted water resources (VUFO-NGO, 2014). Approximately six million Vietnamese people have contracted one of six water-related diseases over the past four years. The expenditures for cholera, typhoid, dysentery and malaria check-ups and treatment are estimated at VND 400 billion ($20.9 million).

According to JMP/UNICEF (2012), the population of Vietnam increased access to water sources from 57 percent in 1990 to 95 percent in 2010, and increased access to sanitation from 37 percent in 1990 to 76 percent in 2010. Although the increased access is rapid and impressive, the country still faces many challenges (WSP, 2012). According to the National Target Programme, only 40 percent of rural population had access to clean domestic water sources in 2010 and 55 percent had access to hygienic toilets. A lack of basic sanitation and drinking water sources coverage has caused negative impacts on the population.

2.2.2 Urban water supply and sanitation in Vietnam

Water supply in urban areas of Vietnam has seen a rapid growth in coverage (ADB, 2010). As of September 2013, 765 cities and towns had water supply covering 32 percent of total population (Nguyen, 2013). Total design capacity of urban water supply system is 6.5 million m^3 per day, and actual operation capacity is 5.7 million m^3 per day. Nearly 80 percent of total urban population is served with water supply systems. The water consumption amount of urban residents ranged from 33 to 213 L/cap/day, averaging at 101 L/cap/day.

Regarding sanitation, more than 90 percent of urban population has access to hygienic toilets and 40-70 percent of the population has access to sewerage and drainage networks (Nguyen, 2010). The networks collect wastewater combined with storm water but most collected wastewater is untreated. Present 18 wastewater treatment plants are possible to treat only about 345,000 m^3/day (approximately 10%) of domestic wastewater out of total 3,080,000 m^3/day. It was estimated that 50-80% of households in large cities use septic tanks, while the ratio in other cities belonging to class 3-5 was 20-50%. A Water and Sanitation Program study (2012) estimated the overall economic costs of poor sanitation in Viet Nam to be US$ 780 million per year at 2005 prices, equivalent to 1.3 percent of gross domestic product (GDP).

2.2.3 Management of wastewater and septic tanks in Vietnam

The lacks of sewerage system have caused water pollution due to direct discharge of wastewater. The rivers and canals in urban Vietnam, especially in large cities such as Hanoi, Ho Chi Minh City, Hai Phong, Hue, Da Nang and Hai Duong are highly polluted. Many open water areas exceeds Vietnam standard on surface water quality. The reason for this pollution is well known as the discharge of untreated wastewater or disposal of solid waste. Regarding wastewater in Vietnam, domestic wastewater discharge accounted for 80% of the total wastewater discharge from urban centers (VACNE, 2004).

At present, the septic tank is the most common on-site wastewater treatment facility (77%) in urban areas of Vietnam but management of septic tanks is at low level (AECOM/SANDEC, 2010). Most of the septic tanks are not regularly desludged and discharged directly to the environment although it is recognized that the septic tanks cannot produce high quality effluent without trench field.

Septic tanks are usually constructed based on practical experience. They mostly do not have accessing port because households have no idea for desludging. A study in Hanoi indicated that more than 90 percent of the residents use septic tanks which are not regular desludged (Harada *et al.*, 2008). Average desludging interval is approximately 8 years. Several reports mentioned that desludging should be conducted every two to five years to recover septic tank performance (USEPA, 2000; UNEP-IETC, 2002). From this information, it can be said that the septic tanks in Vietnam are improperly managed and the performance is at low level.

2.3 Sanitation in Hanoi

2.3.1 General description of Hanoi

Hanoi, which is the capital of Vietnam, is located in the Red river delta (**Figure 2-3**). The city was founded in 1010 as the name of Thang Long, and was renamed as Hanoi in 1831 (UNDP, 2000). Hanoi had an area of 3,300 km^2 and its population was 6.8 million in 2012. Population density was 2,059 people/km^2. The city is composed of 12 urban districts, one town, and 17 sub-urban districts (HSO, 2012).

Figure 2-3 A map of Hanoi (HPC, 2010)

2.3.2 Wastewater and septic tank management

Sewerage and drainage system of Hanoi were constructed from 1905 to 1945 and covered an area of only about 1,000 ha in the city center (Van, 2009). Per capita sewer pipe length was 0.3m/cap (Thai *et al.*, 2005), which was lower than other developing countries (2m/cap). It means that only 35-40 percent of the urban population do benefit from the system (Van, 2009). More than 90% of households in urban Hanoi use septic tanks to treat excreta flushed from toilets and effluent of the septic tanks is mostly connected to the old sewer pipes (Harada *et al.*, 2006). However, most septic tanks have never been desludged. The carry-over of sludge from long-operated septic tank to sewer pipes can be a reason for urban flood.

Hanoi Sewerage and Srainage Ltd., Co. is responsible for the connection of septic tank that is where septic tank effluent goes to. On the other hand, withdrawal of sludge accumulated in septic tank (*i.e.*, septage) belongs to the duty of Urban Environmental Company (URENCO). When a household wants to desludge septic tank, they contact URENCO and pay money. Desludging is also conducted by private company. However, collected septage from private company is often illegally disposed at open water areas in the city. **Table 2-2** compares desludging prices offered by URENCO (*i.e.*, public company) and private company. The price offered by private company is higher than that offered by public company.

Table 2-2 Desludging price by private company and URENCO (Thai *et al.*, 2005)

Type of company	Vacuum truck capacity (m^3)	Desludging price			
		Lower medium		Higher medium	
		VND/trip	VND/m^3	VND/trip	VND/m^3
Private company	2.0	200,000	100,000	400,000	200,000
URENCO	4.0	180,000	90,000	300,000	75,000

1 USD = 15,800 VND in 2005

2.4 Sanitation in Danang

2.4.1 General description of Danang

Danang city is located in the central part of Vietnam. It covered an area of 1,285 km^2 with 973,800 people (**Figure 2-4**). Population density was 758 people/km^2 (GSO, 2012). The city has six urban districts and two sub-urban districts. Because the city is located in monsoon and tropical zone with temperate and less fluctuation, there are two seasons in a year; rainy season from August to December and dry season from January to July. Average temperatures for year is 25.9^oC, average rainfall is 2,504.57mm, sunny hours for year is 2,156.2 hours.

Figure 2-4 A map of Danang (GVP, 2009)

2.4.2 Wastewater and septic tank management

Danang city employs combined sewer system with total length of about 600 km to discharge wastewater to Danang bay and the remaining discharges to East Ocean (SaniCon, 2010). Because of limited drainage capacity, floods occur frequently in some places in the rainy season.

Domestic sewage is mainly wastewater from households and other urban services. Excreta is preliminary treated by septic tank (obliged by building regulation), and grey water is discharged into combined drainage system. Only about 16% of septic tanks is connected to drainage, the remaining is soaked into underground. Groundwater contamination has been investigated at some places.

Danang URENCO has a responsibility for solid waste collection and treatment, drainage system management, and septic tank desludging. In a three cities sanitation project funded by World Bank (WB, 2012), the URENCO initiated regular desludging for 100,000 septic tanks in 2004. The project aimed to desludge 20,000 tanks annually on a five-year rotating cycle. Unfortunately, the project funded desludging only for 33,000 tanks instead of the proposed 100,000 as the project was not integrated into local policies (AECOM/SANDEC, 2010). Collected septage was disposed at a sanitary landfill financed by the project. It is the first landfill in Vietnam that included properly designed cells for treating hazardous waste (WB, 2012).

Table 2-3 Proportion of households having septic tanks connected to drainage in Danang, Vietnam (SaniCon, 2010)

District	Proportion of septic tank (%)	Proportion of connection to drainage (%)
Hai Chau	58.6	38.8
Thanh Khe	93.7	6.0
Son Tra	77.1	22.1
Ngu Hanh Son	97.7	-
Cam Le	89.5	3.6
Lien Chieu	91.6	7.6
Hoa Vang	80.5	3.1
Average	80.4	15.7

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Chapter 3 Characteristics of water consumption and discharge of urban residents

3.1 Introduction

Water consumption and discharge are important factors for water and wastewater management because they are often used as essential data for wastewater treatment design and environmental impact assessment. The common practice of daily water discharge estimation is to assume that 60-90% of per-capita water consumption becomes wastewater (MetCalf and Eddy, 2003) and wastewater quality is often obtained at the inlets to wastewater treatment plants (*i.e.*, WWTPs) (Butler *et al*., 1995). Since wastewater is modified by various in-sewer processes (Almeida *et al*., 1999) and is mixed with other wastewater, water consumption amount and wastewater quality at its origin are important for sustainable water and wastewater management.

Many studies were conducted in developed countries to investigate water consumption amounts and influencing factors to the consumption. According to these studies, household characteristics such as household size and age, their lifestyles, housing types, and types of in-house water facilities affecting water amount consumed by urban residents (Elena and David, 2006; Grothe *et al*., 2009). Even though water consumption is affected by several factors, the data are not much different among areas due to the stability of residential lifestyles in developed cities. On the other hand, the context in developing cities is dynamic because of rapid urbanization and development. These on-going processes result in the replacement of water facilities or the change of water using lifestyles. In addition, urban development has also changed social attitude. Small sized households are becoming popular instead of multigenerational households and elderly people tend to live further away from their children. These changing lifestyles can be the reason for a wide range of water consumption amounts. Moreover, it can be said that water use is not evenly distributed within a day but varied by time according to the occurrence of water consuming activities. These matters should be studied for the improvement of water consumption and discharge knowledge in developing cities.

Regarding wastewater management, developing countries lack both funding to construct and technical expertise to manage and operate sewerage systems, which are well established in developed countries (Massoud *et al*., 2009). Therefore, septic tanks are the most popular on-site facilities at households serving as a complementary treatment as long as the sewerage have not completely constructed. The septic tanks received solely toilet waste and were not frequently desludged. This poor management is the well-known reason for worsening the tanks' treatment efficiency (ADB, 2000). Due to the sewerage limitation, only a small number of septic tanks' effluent is connected to limited combined sewer pipes, the remainings are often discharged into open water areas. The problem is more serious as the existing combined systems and open drainage canals are poorly managed; therefore, the untreated wastewater causes serious water pollution and potential public health risk. Because characteristics of the wastewater flowing in the combined sewers are changed due to not only the inclusion of other wastewater but also in-sewer processes, household wastewater quality should be investigated at its source as a prior for the clear understanding of pollution load from household discharge. In addition, as the wastewater quality varies by time corresponding to the discharge from water consuming activities, at-source wastewater concentration patterns can be a fundamental data for the further knowledge about urban wastewater management, which is a crucial issue in developing cities.

The primary objective of this chapter was to investigate a wide range of per-capita water consumption amounts of residents in urbanized areas and the effects of household size, elderly people, water facilities, and consuming lifestyles on that consumption. As a second objective, we examined hourly consumption patterns associated with hourly water consuming activities that reflect residential lifestyles. Lastly, concentration patterns of at-source wastewater, which was a mixture of greywater and septic tank effluent, were characterized and explained by water consuming activities.

3.2 Materials and Methods

3.2.1 Study site

Hanoi, a capital of Vietnam, has 2,931,300 urban residents, making up 42.8% of total city population (GSO, 2012). Map of Hanoi is illustrated in **Figure 3-1**. In the city center, old single unit houses where multi-generations live together and old apartment buildings were located but the latter are being replaced due to city development. This process also contributes to develop new housing types such as modern apartments and to change residential water using lifestyles. Water supply network covers about 95% of total urban population of Hanoi (HPC, 2012). The population in non-water supplied areas use underground water from private drill-wells. Water meters are installed to measure water volume consumed by households in water supply covered areas. Tanks are often constructed or installed to store water after the water was supplied to household. **Figure 3-2** illustrates water distribution in households. Single unit houses follow the distribution as described in **Figure 3-2(a)** in which water meter is installed before water enters the tank. Each household may have either water tank 1 or water tank 2, or have both tanks depending on the situation. After storage, water is distributed in plumbing system for usage. For apartments, one water meter is installed for a whole building before water enters a tank of the building as illustrated in **Figure 3-2(b)**. Then, measuring water consumption for each household depends on a sub-water meter installed for each apartment. Water bills are delivered monthly to households to collect water consumption fee. So far, several researchers reported water consumption amount in Hanoi. Busser *et al*. (2006) showed the daily-per-capita consumption as 170 L, while the city government indicated it as 130-140 L based on production data of water supply plants (HPC, 2012). These studies showed only the average daily amount per person not its variation associated with water consuming activities.

Similarly to many cities in developing countries, Hanoi suffers from water pollution due to improper wastewater management. It was estimated that about 330,000 m^3 of wastewater was discharged from the city's center, two-third of which came from domestic activities (Francisco and Glover, 1999). Because of the limitation of sewage treatment coverage (approximately 7%), more than 90% of household wastewater in urban areas has been discharged into open water areas after poorly performed septic tanks (Harada *et al*., 2008). As a result, improper domestic wastewater management was recognized as one of major reasons for serious river pollution in the city. For the improvement of urban wastewater management, recent development of modern sewerage is now providing more information on wastewater compositions obtained at the inlets of WWTPs. However, the influents of WWTPs are diluted by unknown water included and changed by processes occurring in the sewers comparing with original wastewater.

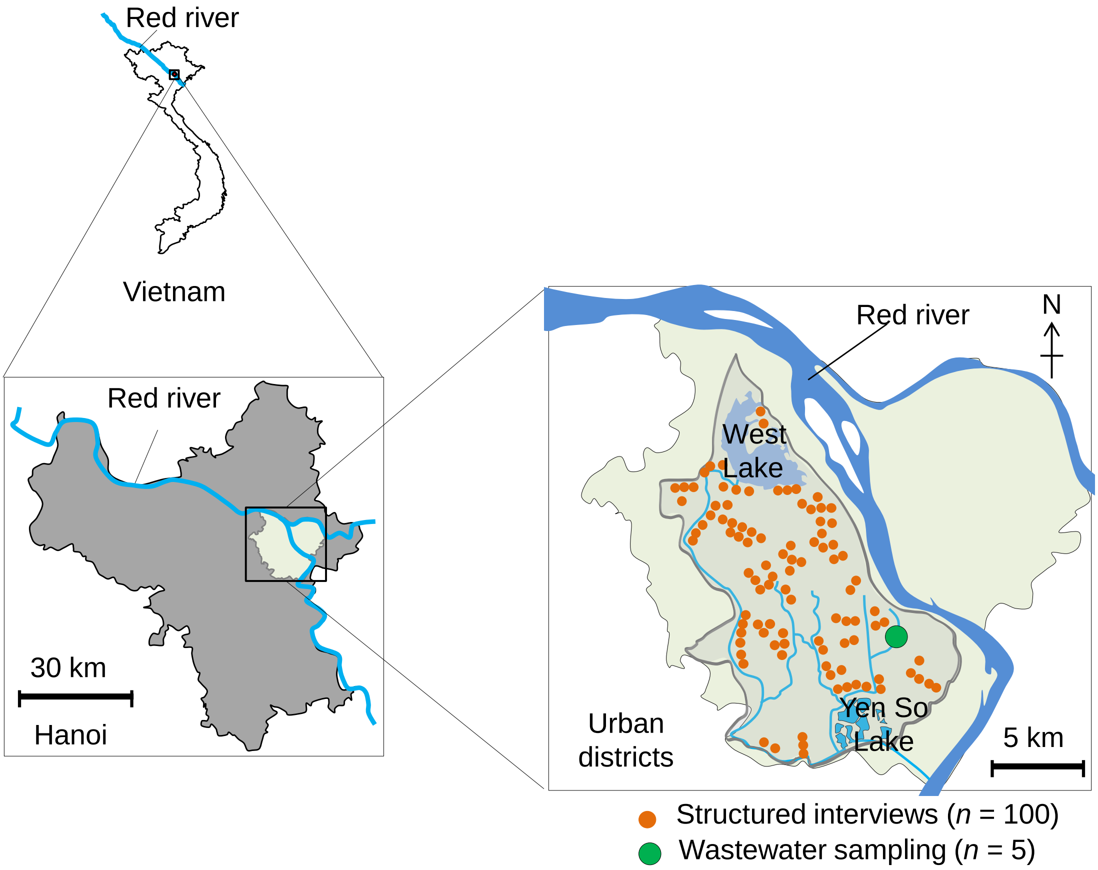

Figure 3-1 Map of sampling in Hanoi including structured interview and wastewater sampling

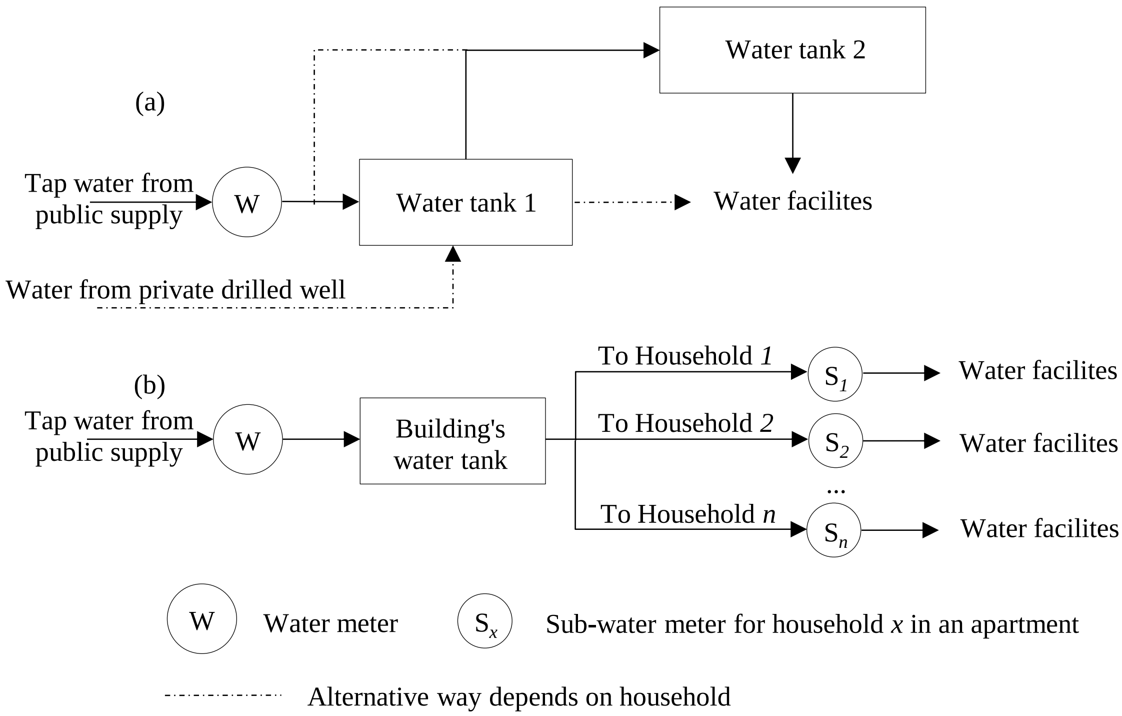

Figure 3-2 Distribution of water in households using tap water from public water supply: (a) single unit house; (b) apartment. Some households keep using underground water from private drilled well. Water tank 1 is often constructed on-ground or underground while water tank 2 is often installed on-roof. This chart does not include rain water and bottled water.

3.2.2 Daily per-capita water consumption survey

A structured interview was conducted for 100 households in residential housings situated in urban areas of Hanoi in December 2012 (**Figure 3-1**). Contents of the interview included information about household attributions, types of water sources, types of in-house water facilities, and water consuming lifestyles are listed in **Table 3-1**. We also collected water consumption amount of three consecutive months (September, October and November) measured by tap water-meter mentioned in water bills to estimate the average water consumption amount (L/cap/day).

The average daily-per-capita water consumption was calculated based on **Equation 3-1**.

$$V_{person} = \frac{\sum_{i=1}^{3} V_i}{\sum_{j=1}^{3} d_i} \times \frac{1}{n} \times 10^3 \quad \textbf{(Eq. 3-1)}$$

in which V_{person} is the average daily-per-capita water consumption (L/cap/day); V_i is water consumption of month i of three consecutive months (m^3); d_i is the total number of day of month i (day); and n is the household size (number of people).

Table 3-1 Contents of structured interview on water use pattern

Item	Content
Household attribution	Number of household members
	Age structure
Types of water source	Tap water from public water supply network, private drilled well water, rainwater, bottled water
In-house water facility	Types of toilets (pour-flush toilet or cistern flush toilet)
	Presence of a bath-tub
	Presence of a shower
	Presence of a washing machine
	Presence of a kitchen sink
Water consuming activity	Bathing (use a bath-tub*, use a shower**, use a bucket†(*i.e.*, pour-bathing)
	Clothes washing (by a washing machine, by hands)
	Kitchen activities (use a kitchen sink, use a traditional plastic tub)

Note: * use a bath-tub: feeding water in a bath-tub

** use a shower: use a shower directly

† use a bucket: feeding water from a shower to a bucket and then use a smaller bucket to pour water to the body

3.2.3 Average hourly per capita water consumption survey

Water consumption amounts were continuously recorded within 48 hours (*i.e.*, two consecutive days) for each of ten modern apartments based on a water meter of each apartment. The survey was conducted within 00:00 (Monday) - 24:00 (Tuesday), 00:00 (Tuesday) - 24:00 (Wednesday) and 0:00 (Wednesday) - 24:00 (Thursday) for four households, two households, and four households, respectively.

The households were also given diary sheets and requested to record the period and frequency of water consuming activities. The activities were composed of hygienic practice such as face washing, tooth brushing and hand washing, toilet use, bathing/showering, laundry, cooking, dish washing, and others such as house cleaning and bonsai watering. When each activity occurred, the households mark it with corresponded time with a slash (/) (**Table 3-2**).

Table 3-2 Example of a checklist to record hourly water-consuming activities

Time	Hygienic practice	Toilet use	Bathing/ Showering	Laundry	Cooking	….
0-1 AM	//					
1-2 AM		///				
….						/
10-11 PM			/			
11 PM-12 AM		/				

3.2.4 Household wastewater sampling and analysis

We sampled wastewater from five households. Sampling point of the wastewater was illustrated in **Figure 3-3**. Human excreta were flushed into toilets, and then were discharged into septic tanks. Septic tank effluent and greywater were discharged into an outside underground pit (~30 L). After that, the mixed wastewater in the pit flowed to the canal through a few meter PVC pipe, at which wastewater samples were obtained. The sample was assumed not to be degraded after generation of wastewater and regarded as a sample of at-source wastewater.

The discharged amount was measured every hour by graduated buckets during 24 hours. Wastewater was sampled every three-hour interval during the discharge measurement, starting at 0 AM by sampling method applied for all samples as follows. All the water discharged during 0 AM to 1 AM was collected and mixed carefully to obtain a composite sample representing for 0-1 AM. A part of the collected wastewater at six-hour intervals was filtered to make a soluble sample, and both of original (total) and soluble samples were analyzed for COD_{Cr}, BOD_5, SS, TKN, and (**Table 3-3**). The samples at three-hour intervals were analyzed for only COD_{Cr} and BOD_5. All of the parameters were analyzed by the Standard Methods (APHA, 2005).

Table 3-3 Description of sampling time and analytical parameter

Sampling time	0-1 AM	3-4 AM	6-7 AM	9-10 AM	12-1 PM	3-4 PM	6-7 PM	9-10 PM
Analysis	**	*	**	*	**	*	**	*

Note: **COD_{Cr}, BOD_5, TKN, TP (total and dissolved concentrations), SS
*COD_{Cr} and BOD_5 (total concentration)

The average wastewater concentrations were calculated for five households based on **Equation 3-2**.

$$C_{ave.,k} = \frac{1}{20}\sum_{m=1}^{5}\sum_{t=1}^{n} C_{k,m,t} \quad \textbf{(Eq. 3-2)}$$

in which $C_{ave,\ k}$ is the average concentration of parameter k (mg/L); $C_{k,m,t}$ is the concentration of parameter k of household m (m = 1, 2,… 5) at time of sampling t (mg/L); n = 8 for COD_{Cr} and BOD_5 and n = 4 for TKN, TP, SS, VSS, *E. Coli* and Total coliform.

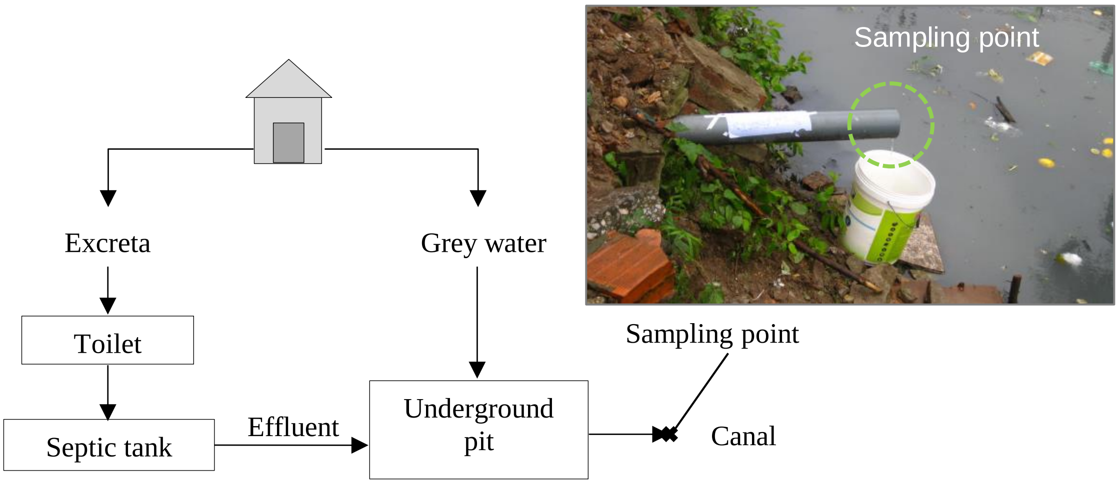

Figure 3-3 Illustration of household wastewater discharge and sampling point

3.3 Results and Discussions

3.3.1 Average daily-per-capita water consumption and residential lifestyles

The proportion of different water supply modes in the target area is shown in **Table 3-4**. The water supply modes were composed of tap water from public water supply, private drilled well water, and bottled water for daily life. Tap water users accounted for 95% of total surveyed households, in which 4% used private drilled well water as well. They keep using private drilled well even after they were able to connect public supply network. Ten percent of total surveyed households bought bottled water for drinking.

The average daily-per capita consumption amounts calculated for tap water users are presented in **Figure 3-4**. A wide data range was observed but residents mostly consumed the amount between 100-170 L/cap/day peaking at 140 L/cap/day, then followed by 170 L/cap/day and 100 L/cap/day, respectively. The average consumption amount of this study was 146$\pm$58 L/cap/day. Median value was 133 L/cap/day. This amount was less than the average data of 28 East Asian cities but higher than that of 12 and three cities in Southwest Asia and Central Asia, respectively (**Table 3-5**). Noticeably, average daily-per-capita consumption amount of the U.S. was much higher than other data. This big water consumption in U.S. was understood as the results of high toilet flush, bath and shower volumes and frequencies (Butler *et al*., 1995).

Table 3-4 Proportion of water supply modes (%) in the target area (*n* = 100)

Water supply mode	Proportion
Tap water from public water supply	95%
Private drilled well	9%
Bottled water	10%

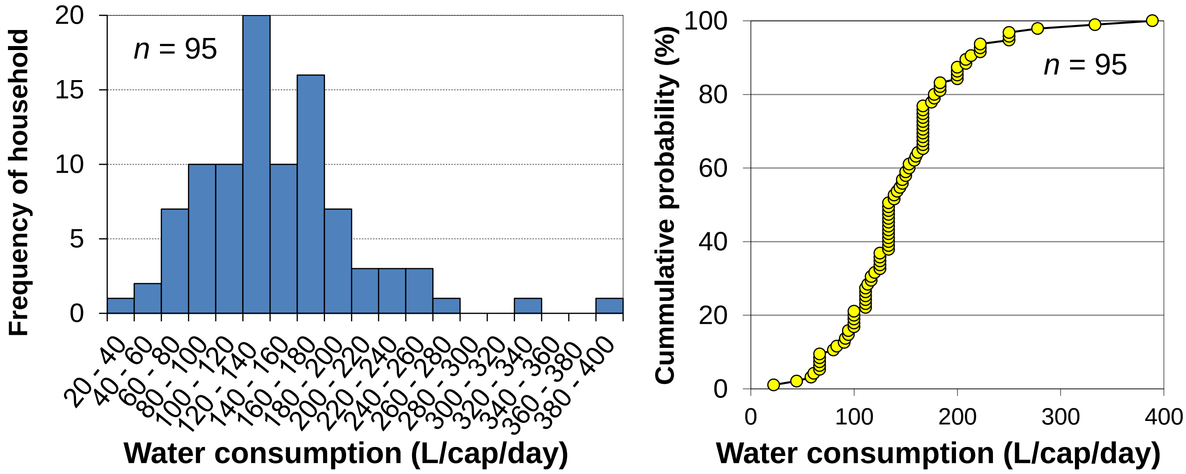

Figure 3-4 Average daily-per-capita water consumption of tap water users (*n*=95)

Table 3-5 Average daily-per-capita water consumption of different locations (data collection methods might be different)

Location	Data number (*n*)	Average daily-per-capita water consumption (L/cap/day)
This study	80	146±58
Central Asia (IDI, 2004)	3	136
Southwest Asia (IDI, 2004)	12	144
East Asia (IDI, 2004)	28	151
Japan (JMLTT, 2009)	not available	296
U.S. (MetCalf & Eddy, 2003)	not available	382

Regarding the effect of lifestyle on water consumption, it was known in the context of developed countries that per-capita water consumption is negatively correlated to a household size (*e.g.*, Domene and Sauri, 2006; Loh and Coghlan, 2003). However, as shown in **Figure 3-5** such a clear trend was not observed in this study even though the household sizes were widely distributed in the target households. An interesting finding is that there is a significant difference (p < 0.001) between with and without the presence of elderly people in a household on their per-capita water consumption (**Table 3-6**).

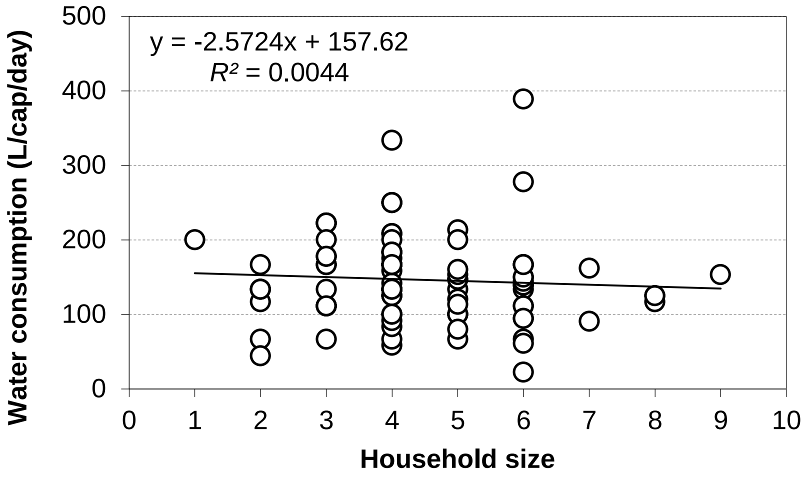

Figure 3-5 Average daily-per-capita water consumption for different household sizes (*n*=91).

Table 3-6 Average daily-per-capita water consumption of households using only tap water from public water supply (*n* = 91) by different lifestyles (Average ± Standard deviation)

Household (HH) characteristic	Data number (*n*)	Water consumption (L/cap/day)	Significant difference
HH and elderly people			
HHs with elderly people	36	121 ± 38	$p < 0.001$
HHs without elderly people	55	163 ± 62	
Toilet types			
HHs with pour-flush toilet	8	116 ± 30	Not significant
HHs with cistern-flush toilet	83	150 ± 60	
Washing machine			
HHs wash clothes by hand	1	90	Not significant
HHs use only washing machine	90	148 ± 58	
Bathing lifestyle			
HHs do pour-bathing	4	139 ± 42	Not significant
HHs use shower	85	145 ± 60	
HHs use bath-tub	2	225 ± 35	
Kitchen facility			
HHs with a small plastic tub)	7	113 ± 31	Not significant
HHs with kitchen sink	84	150 ± 59	

Figure 3-6 shows the proportion of households with and without the elderly versus per-capita consumption amount. To check the effect of the presence of the elderly, the water-related lifestyle of households was compared between households with and without the elderly in (**Table 3-7**). The traditional water saving manner was especially observed with households with the elderly such as laundry by hands, pour-flush toilet use, bathing by bucket pouring and cooking and dishwashing in a small plastic tub. Those manners would generally consume less water for each purpose than modern manner such as laundry by machine, cistern-flush toilet use, bathing by a shower device/bath tub, and cooking and dishwashing in a modern kitchen sink. These results may disclose that the presence of the elderly may induce different types of water saving practices in a household. On the other sides, households with traditional manners had small sample sized for each item, except the presence of the elderly, and any significant difference was not observed with single manner (**Table 3-6**).

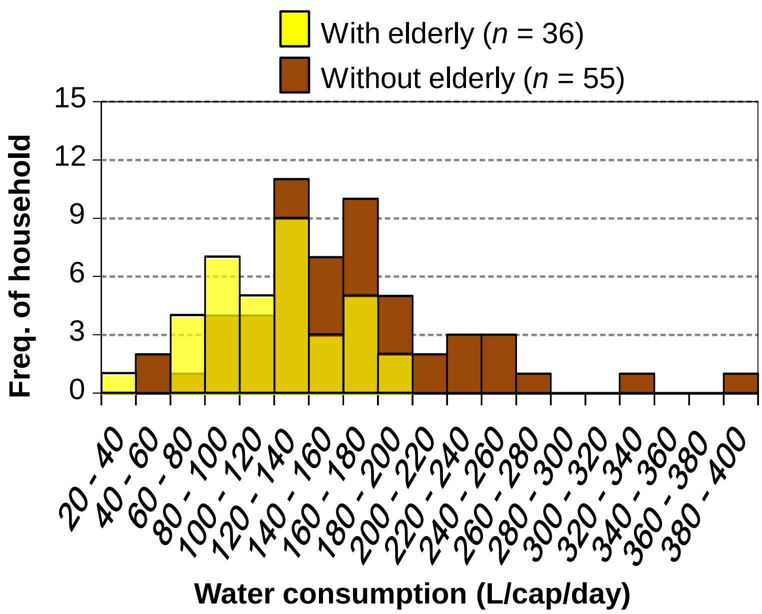

Figure 3-6 Proportion of households versus average daily-per-capita water consumption (L/cap/day) of households with the elderly (n = 36) and without the elderly (n = 55).

Sole-parent households are increasing in developed countries and young generation is also likely to live alone (OECD, 2011), which is understood that multi-generational households is generally exist more in developing cities than developed cities. As indicated in this study, traditional water saving manner may conserve more in those households, and the presence of the elderly may become a kind of indicator of hidden water saving effects of those families in developing cities. At the same time, the number of those families is decreasing even in developing cities; it is expected that water saving effect by traditional water practice will be declined gradually.

Table 3-7 Proportion of households (%) with and without elderly people versus different water using behaviors

Water-consuming behaviour		Household: With the elderly (n = 36)	Household: Without the elderly (n = 55)
Washing manner	Washing machine	97	100
	Hands	3	0
Toilet use	Normal-cistern flush	39	67
	Water-saving cistern flush	53	31
	Pour-flush	8	2
Bathing manner	By a bath-tub	0	4
	By a shower	89	96
	By a bucket	11	0
Kitchen activity	Use a kitchen sink	83	98
	Use a traditional plastic tub	17	2

3.3.2 Hourly water consumption and water consuming activities

Pattern of water use activities and consumed amount

Figure 3-7 shows average hourly water consumption within two consecutive days for ten households living in modern apartments. Water consumption patterns for day 1 and day 2 showed a similar trend with low morning peak and higher evening peak, and no flow at late night. This trend can be explained by water consuming activities that reflect lifestyles of urban residents. Hygienic practice and toilet use happened almost a whole day except 2-4 AM. This implies a contribution of these activities to water consumed every hour. Distribution of bathing/shower and laundry presented two peaks, while that of cooking and dish washing showed three peaks. It can be understood that the former importantly contributed to the two peaks of hourly consumption patterns, while the latter was less contributed.

The official office hour in Hanoi is from 8 AM to 5 PM. Primary school pupils attend the schools for whole daytime. Other school students go to schools from 7:15 AM to 11:45 AM in the morning and 1:15 PM to 16:45 PM in the afternoon. The morning peaks corresponded to residents preparing to go to work and school. The peaks occurred between 4-9 AM with maximum values at 7-8 AM of 9.8 L/cap/h for day 1 and 9.3 L/cap/h for day 2. This period witnessed the occurrence of all activities, and quite high frequency of toilet use. Another small peak around 10 AM-2 PM was observed: it is explained by their lifestyle that a considerable proportion of people working/schooling outsides have a lunch in their house except primary school students who have school lunch.

Per-capita water consumption in morning session (4-10 AM) accounted for 18.7% (27 L/cap) of total consumption within a day. Similarly, day time session (10 AM-5 PM) contributed 19.6% (28 L/cap) to overall consumption. The evening session (5-11 PM) was the biggest contributor of 57% (82 L/cap) whereas midnight session (11 PM-2 AM) was the lowest one of 4.7% (7 L/cap).

Previous studies (Butler *et al*., 1995; Almeida *et al*., 1999) indicated a significant importance of toilets by contributing 30-40% to total water consumption. The toilets in this survey contributed about 20% to total water consumption. It can be said that together with other activities toilet use was the important contributors to the morning water use. Because we considered hand washing as one of hygienic activities, the similar trend between hygiene and toilet flush can be recognized as hygienic practice after toilet use.

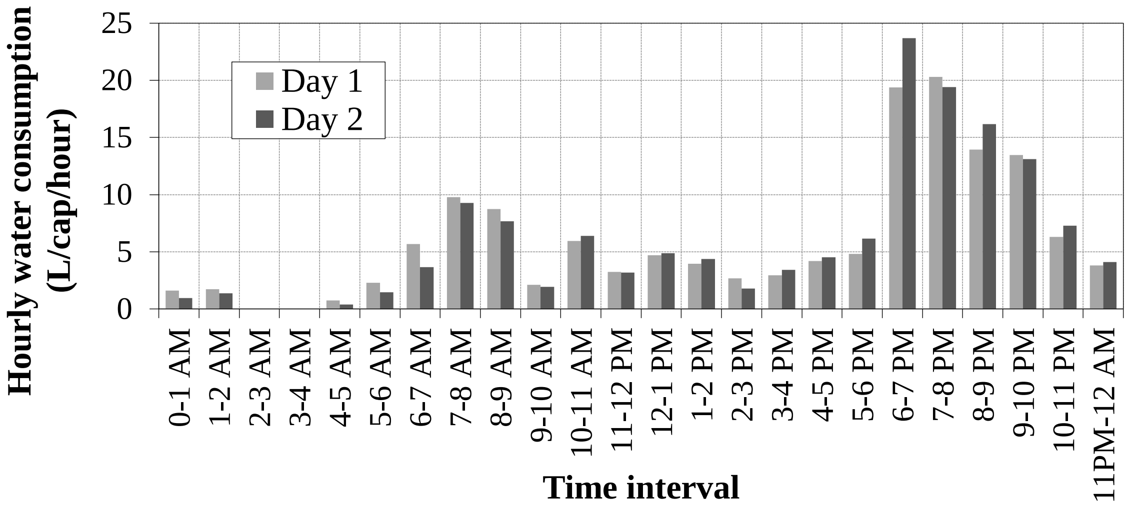

Figure 3-7 Average hourly-per-capita water consumption for two consecutive days of ten households

The effect of household, hour, and day on water consumption are analyzed by three-way layout of ANOVA (**Table 3-8**). The analysis could not explain 18.3% of the data. It can be seen that there was no effect of day as well as the interactions between hour and day, and household and day. On the other hand, the hour had the strongest effect ($p < 0.001$) on water consumption by its biggest contribution (42.04%) to explain the data. Although contribution of household effect was small (4.07%), it was significant ($p < 0.001$). The interaction between household and hour also significantly affected ($p < 0.001$) water consumption by the contribution of 36.35% to data explanation. Since consumption data were recorded on weekdays, the data analysis discloses that water consumption is a daily routine and each household has their own water consumption pattern which varies hourly.

Pattern of water use activities and indicated lifestyles

Lifestyle of the residents could be indicated by the water consumption data. As show in **Figure 3-8**, bathing/showering, laundry, cooking and dish washing had clear peaks, while hygienic practice and toilet use happened almost throughout a day except 2-4 AM. The clear peaks of bathing/showering and laundry in the evening and morning occurred almost the same timing to the distinct peaks of hourly water consumption; it corresponds to Busser *et al.* (2006) that bathing and showering produced the highest amount of greywater in Hanoi.

Table 3-8 Three-way layout of ANOVA for hourly water consumption data (10 households * 2 days * 24 hours)

	Sum of squares	Degree of freedom	Unbiased variance	Proportion of variance	*p* value	Modified sum of squares	Contribution (%)
Total	37596	479	78			37596	100
Eff. of hour	16134	23	701	48.9	0.00000	15804	42.04
Eff. of HH	1660	9	184	12.9	0.00000	1531	4.07
Eff. of day	1.7	1	2	0.1	0.73149	-13	-0.03
hour*HH	16631	207	80	5.6	0.00000	13665	36.35
hour*day	176	23	8	0.5	0.96171	-154	-0.41
HH*day	26	9	3	0.2	0.99342	-103	-0.27
Residual error	2967	207	14			6865	18.3

For more detailed lifestyle indicated by the pattern of water using activities, the peak of dishwashing (8-9 AM, 11 AM-12 PM, and 7-8 PM) happened one or two hours after that of cooking (7-8 AM, 10-11 AM, and 5-6 PM) as generally understood. Evening bathing/showering accounted for 78% of the total; the peak of bathing/showering (6-8 PM) happened one hour after cooking (5-6 PM), which reflects their lifestyle that urban residents in Hanoi mostly do a bathing/showering after dinner. In the past, Hanoian often took a bath before dinner might be due to no hot shower. However, as all houses have been equipped with hot shower facilities, residents have changed their lifestyle by having a bath/shower later even at late night.

Laundry also occurred mainly in the evening (6-10 PM) with 70%. Residents used to wash clothes in the morning to dry outside but they have changed the habit to the evening because the washing machine allows the washed clothes drier compared to washing by hands. The residents often do laundry after a busy day with working/schooling, and then drying is placed at the roof-covered balcony. The peaks of laundry likely occurred after bathing/showering but the distributions did not clear differed from each other.

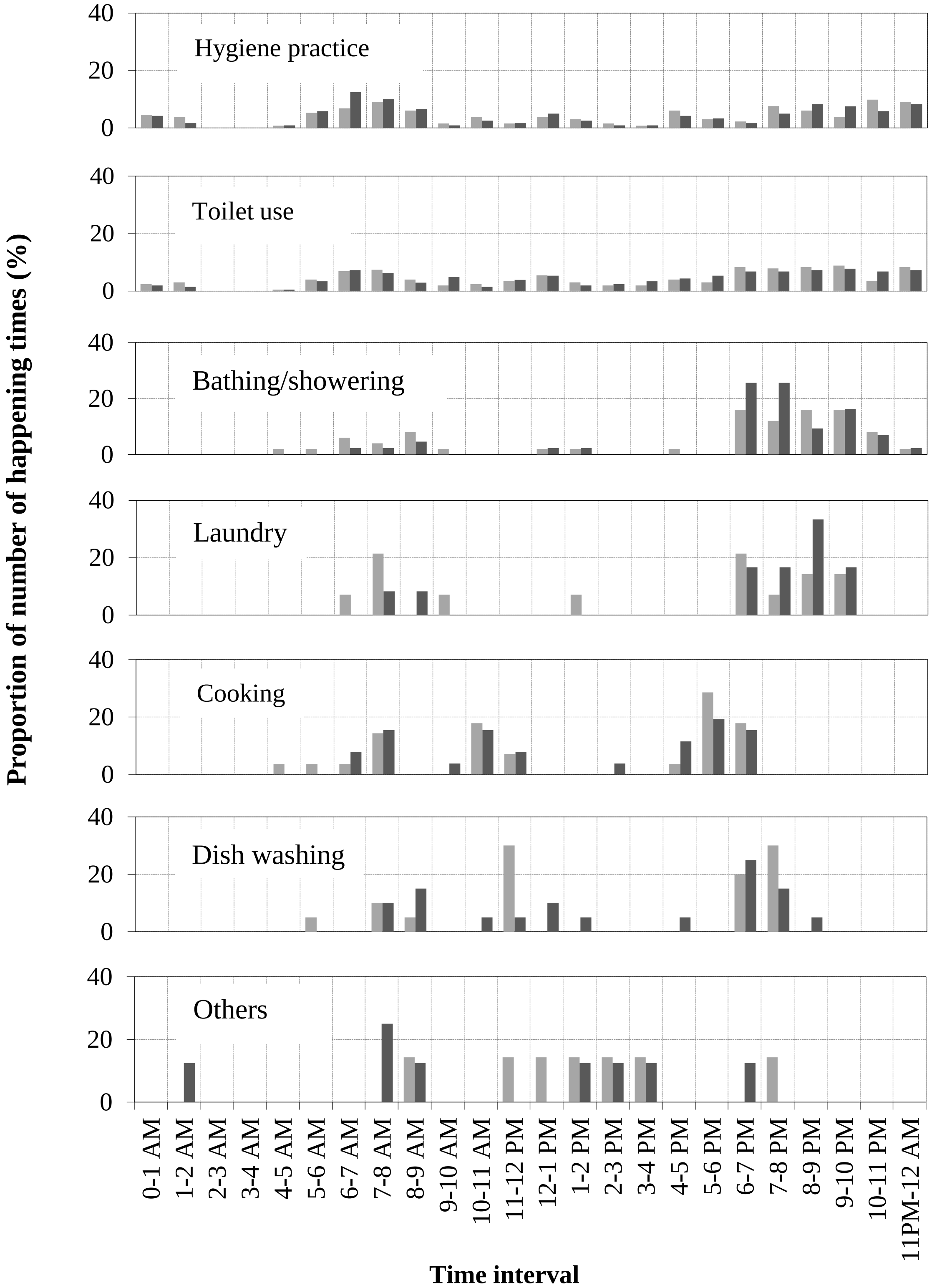

Figure 3-8 Hourly water consuming activities for two consecutive days of ten modern apartment households: proportion of hourly number of times with unit activities. Other activities are bonsai watering and house cleaning.

Toilet use and hygiene are the two dominant activities in the midnight, indicating their bed time preparation. This trend is similar to that mentioned in another study investigating the significant contribution of toilet to total water flow in the nighttime (Butler *et al*., 1995).

Relation between water consumption and water-consuming activities

Correlation between water consumption and water-consuming activities was investigated by Multi-linear regression analysis as shown in **Equation 3-3**.

$$Y = \sum_{i=1}^{7} a_i \times X_i + constant \qquad \textbf{Eq. 3-3}$$

in which Y is water consumption; a_i is coefficient of each water-consuming activity; X_i is water consuming activity in this study such as hygienic practice, toilet use, bathing/showering, laundry, cooking, dish washing, others.

Correlation between water consumption and each activity are presented in **Table 3-9**. It shows that the water consumption (Y) was significantly correlated to the water-consuming activities X_i ($p < 0.001$, $R^2 = 0.9394$) (**Table 3-10**). Water consumption can be a function of each activity as follows.

$$Y = 0.6X_1 + 1.3X_2 + 12X_3 + 10X_4 + 4.4X_5 + 7.9X_6 + 11X_7 + 0.26$$

Bathing/showering and laundry had the strongest ($r_{y3} = 0.90$) and second strongest ($r_{y4} = 0.78$) correlation to water consumption as the peaks of these activities were similar to those of water consumption. It may disclose that these activities consumed big water amount. Toilet use was also found to have the strong correlation to water consumption ($r_{y2} = 0.70$). As calculated in previous section, the use of toilet contributed about 20% to total water consumption. Dish washing also had a high effect on water consumption with ($r_{y6} = 0.6$). Hygienic practice and cooking had a weak correlation to water consumption, showing that water volume consumed for these activities may be small.

Table 3-9 Summary of multi-linear regression analysis on water consumption with all activities ($p < 0.001$, $R^2 = 0.9394$)

Item	Symbol	a_i	Correlation (r_y)
Water consumption	Y		
Hygienic practice	X_1	0.6	0.34
Toilet use	X_2	1.3	0.70
Bathing/ showering	X_3	12	0.90
Laundry	X_4	10	0.78
Cooking	X_5	4.4	0.20
Dish washing	X_6	7.9	0.60
Others	X_7	11	0.10
Constant		0.26	

Table 3-10 *F* test for linear regression analysis

Variation	Sum of squares	Degree of freedom	Unbiased variance	Proportion of variance	*p* value
Total	1631	47			
Regression	1538	7	219.701	91.906	0.00000
Residual Error	93	39	2.390		

3.3.3 Household wastewater characteristics

Wastewater composition from five detached households was exhibited with eight parameters in **Table 3-11**. Considering the average values of all households, the ratio between BOD_5/COD_{Cr} was 0.48 and this ratio lied within the typical range for untreated municipal wastewater (0.3-0.8) (MetCalf and Eddy, 2003). Apart from the point that wastewater quality will be high if water consumption is low (IDI, 2004), BOD_5 concentrations in this survey were much lower than the data referenced from other countries except Japan in spite of the low water consumption. Because Japan employs separated sewerage systems and the data were the average concentration at the inlets of

1,535 WWTPs, one possibility for the low BOD_5 concentration is the degradation in sewer pipes.

The suspended solid concentration was also much lower than other referenced data. The ratio between SS/COD_{Cr} was 0.15 which implied that organic matter was mainly soluble. As already mentioned, the samples were the mixture of greywater and septic tank effluent after a pit. Harada *et al.* (2008) investigated low performance of the septic tanks in Hanoi due to non-regular desludging The low SS concentration might indicate that treatment efficiency of the non-desludged septic tanks was limited, enabling to trap only particulate matter. The results showed that the wastewater contained high organic contents, nutrient levels, and concentrations of Coliform bacteria, which may pollute receiving water environment if not properly treated. In fact, the local canal receiving the wastewater was polluted with dark color and foul odor. From these points, further treatment of household wastewater is essential in addition to current septic tank installation to protect water environment and prevent potential health risk.

Table 3-11 Household wastewater composition of different locations

Item	Unit	Wastewater composition							
		Hanoi (this study)	Danang (SaniCon, 2010)	Malaysia (Kling, S., 2007)	Bangkok (Sanicon, 2010)	Kathmandu (Sanicon, 2010)	Shenzhen (Sanicon, 2010)	Japan	MetCalf & Eddy (Medium
COD	mg/L	471±152	100-300	420		300	450	94*	430
BOD_5	mg/L	225±121	100-200	239	56	200	200	190	190
TKN	mg/L	57±6	10		12.4	10	45 (NH_3-N)	29.3	40
TP	mg/L	8±2	2		1.2	2	6	3.9	7
SS	mg/L	80±26	200-400	103	109	500	220	161	210
VSS	mg/L	59±27							
E. Coli	CFU/100mL	$3.5\times10^5\pm2.8\times10^5$							
Total coliform	CFU/100mL	$5.1\times10^5\pm2.3\times10^5$							

Note: * is NH3-N, ** is COD determined using penmagemate potassium

Detailed concentration patterns of wastewater composition are illustrated in **Figure 3-9** and **Figure 3-10**. The COD_{Cr} and BOD_5 were observed at higher concentrations during 12-4 PM peaking at 3-4 PM, and the TKN and TP concentrations were found to peak at 12-1 PM. In the previous section of hourly water consumption, it was realized that toilet use was the major activity to consume water during 12-4PM. Toilet waste was flushed into the septic tanks having 8-15 year operation without desludging in this survey.

Because toilet discharge was specified to represent the highest contribution to COD production (Almeida *et al*., 1999) and produce most part of ammonia in wastewater (Butler *et al*., 1995), it can be understood that treatment efficiency of the septic tanks was limited. In addition, this period was the time consuming the lowest water amount in comparison with other periods. Therefore, the polluted effluents were little diluted and then remained highly concentrated in the released wastewater.

The wastewater concentrations then sharply decreased in the evening (6-7 PM). This time period witnessed the high frequencies of water-consuming activities. The wastewater was much diluted due to a large amount of water released from bathing/showering and laundry. Although the TP concentrations also decreased, it was still high and may be understood as the discharge from laundry. In the night time where almost no activity was recorded, slow wastewater flow was continuously collected. This may be explained that the wastewater remained in plumbing system gradually discharged even no activity occurred. The wastewater concentrations increased in the morning (6-7 AM) and from then continued to rise during daytime (9 AM-12 PM). Toilet use was indicated as the important contributor to discharge water during these periods. However, wastewater concentrations at 6-7 AM were higher than the concentrations at 9-10 AM and can be explained as follows. The concentrations at 6-7 AM was more diluted by water consumed for other morning activities whereas concentration at 9-10 AM was less diluted due to few water consuming activities happened.

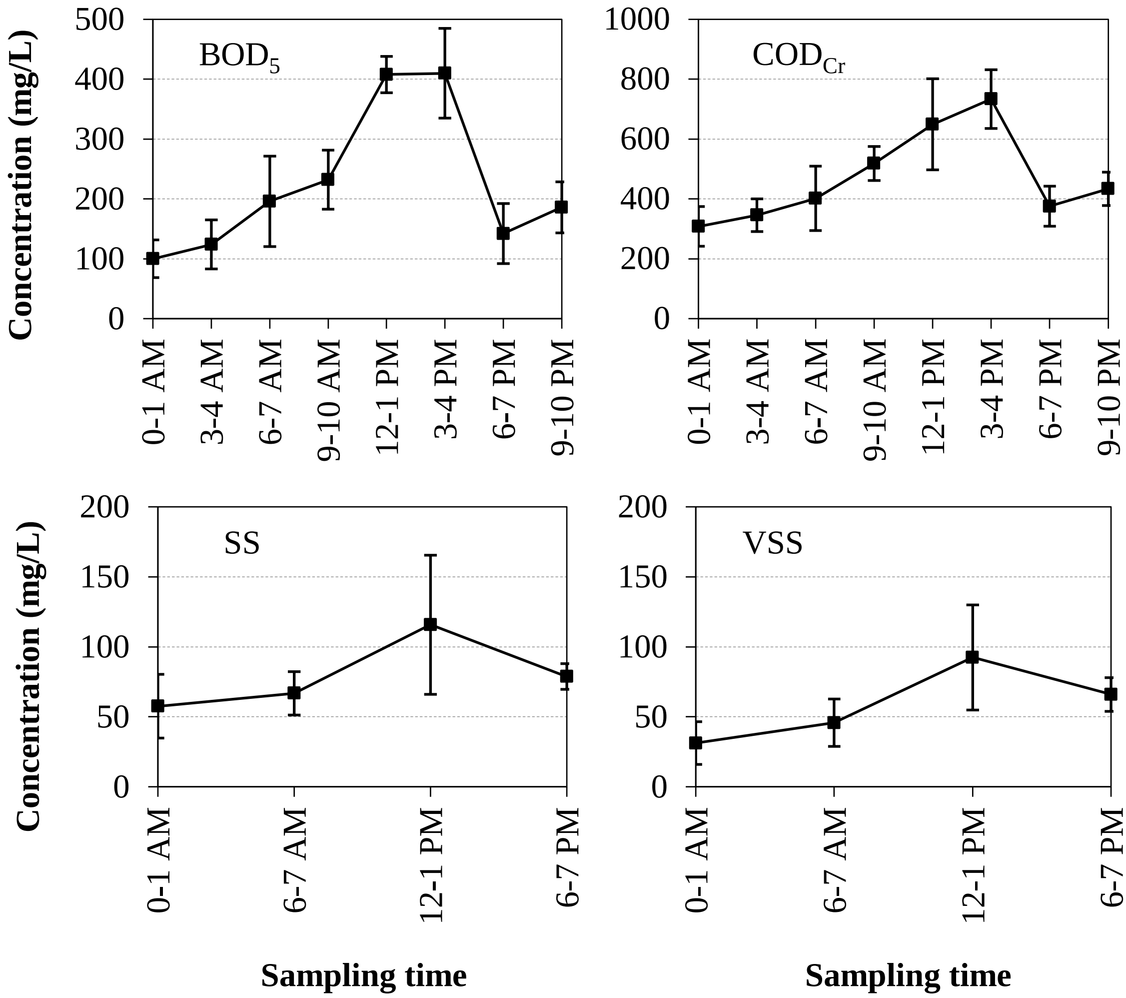

Figure 3-9 Wastewater concentrations from five households for BOD_5, COD_{Cr}, SS and VSS. The wastewater was the mixture of greywater and septic tank effluent and obtained right after it was released.

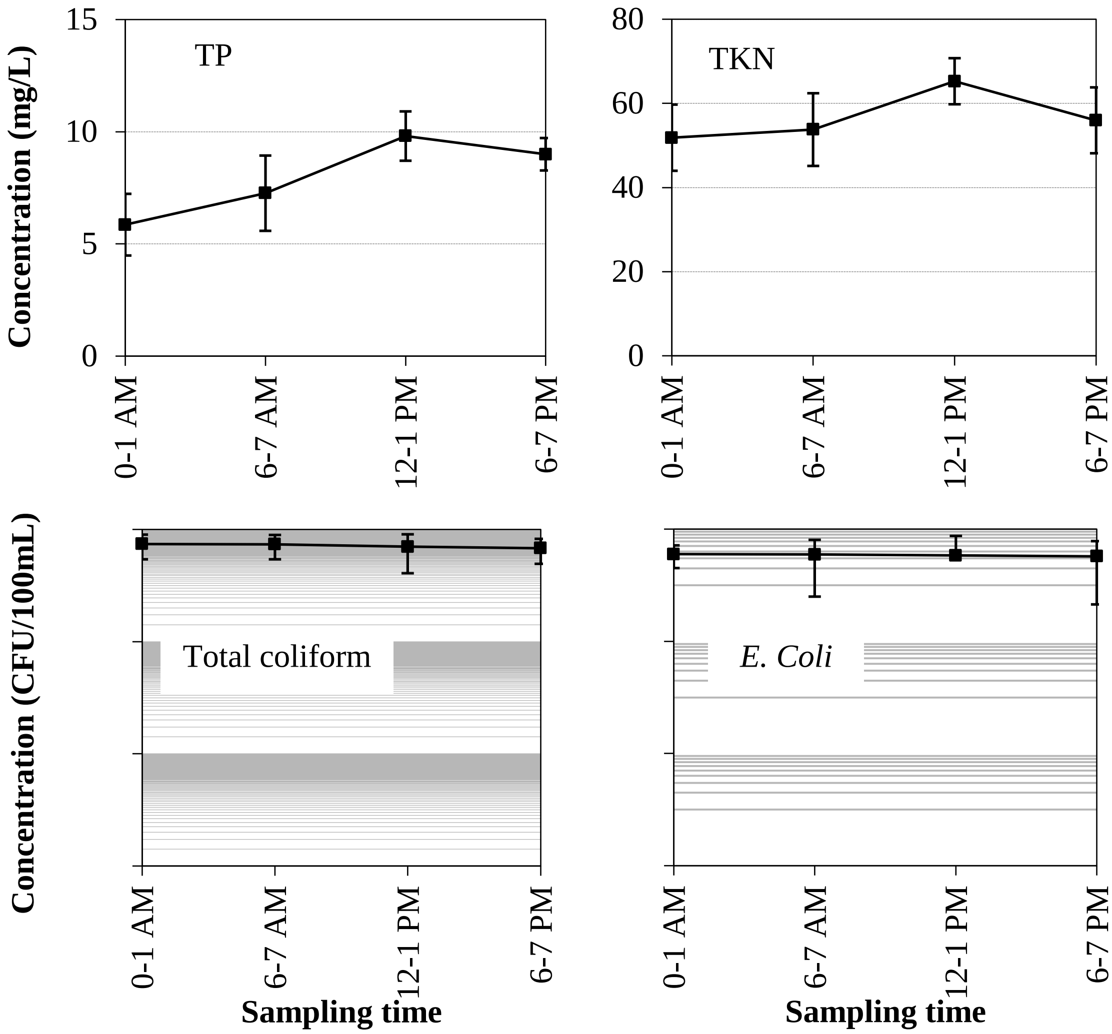

Figure 3-10 Wastewater concentrations from five households (continued) for TP, TKN, Total coliform, *E. Coli*. The wastewater was the mixture of greywater and septic tank effluent and obtained right after it was released. Total coliform and *E. Coli* are presented in log-scale.

3.4 Conclusions

The current study assessed the relation between residential lifestyles and water use pattern in urbanized areas of developing cities. The paper firstly presented a wide range of per-capita water consumption amounts (146±58 L/cap/day) due to the diverse lifestyles, which could not be observed in developed cities. We evaluated the effects of the water facility modernization, the change in water using lifestyles, the household size reduction, and the elderly on the water amounts. The recorded frequencies of toilet use, hygienic practices, bathing/showering, laundry, and kitchen activities occurring within a day reflected hourly water consumption and wastewater quality patterns.

The replacement of water facilities with the modern ones and the way of bathing by shower or bath-tub instead of traditional pour-bathing tended to increase per-capita water consumption. Interestingly, the elderly presence showed the negative relation by decreasing that amount probably due to their less use of toilet and washing machine, or less frequency of showering or showering amount. Toilet use was also found to have important contribution (20%) to daily water consumption. On the other hand, bathing/showering and laundry were the major activities for evening consumption, contributing 78% and 70% to total happening times, respectively. Bathing/showering had the strongest correlation (r=0.90) and laundry had the second strongest correlation (r=0.78) to water consumption. Toilet use also strongly correlated to water consumption (r=070). Because of toilet discharge with little dilution at 3-4 PM, the highest wastewater concentrations were observed at this period. Although no activity happened at late night during sleeping hours, the wastewater remained in plumbing system still gradually discharged. The septic tanks played a role for toilet waste treatment but were able to trap only particulate matter due to poor performance. Therefore, further treatment should be considered for the protection of water environment and the prevention of potential health risk as most household wastewater was discharged into open water areas in developing cities.

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Chapter 4 Household pollution loading and evaluation of septic tanks' function

4.1 Introduction

Global population is rapidly increasing and the major growth will take place in urban areas of developing countries, leading to the increase in wastewater production (UN-HABITAT, 2010). In many urban areas of Asian developing countries where central wastewater treatment systems are not popular, most households rely on septic tanks for the pre-treatment of toilet waste (Koné D. and Strauss M., 2004). However, due to improper management, the septic tanks have low efficiency. Greywater and septic tank effluent from households without sewer connection are discharged directly into nearby open water areas. The wastewater from households connected to sewer system is only partially treated together with storm water because of limited wastewater treatment capacities. Untreated wastewater may deteriorate water quality and threaten public health by its organic materials, nutrients, toxic substances and pathogens. Therefore, the estimation of household pollution loading would be essential for a better management of urban wastewater.

Estimation of household pollution loading is quite important to understand current major pollutant sources, and to know the countermeasures for conservation of water environment, essentially in the area where most of wastewater is discharged directly without treatment. Household pollution loading varies with water consumption rates and wastewater characteristics, so that the exact estimation by observations is not an easy task, resulting in inadequate information in developing countries.

This chapter aims at estimating the pollutant loading by observations in an urban area in Hanoi, Vietnam. Water consumption rates were hourly observed during 48 hours at 10 households, and wastewater characteristics were measured with six-hour intervals at five households. Similarly, hourly observation of flow rates and six-hour intervals' measurement of water quality were conducted near the inlet and the outlet of the river where these households discharged their wastewater. Finally, the pollution loading of household wastewater was compared to the loading from the watershed (*i.e.*, accumulated loadings in the river water), and the function of septic tanks was evaluated.

4.2 Materials and Methods

4.2.1 Study site

Hanoi, the capital city of Vietnam, suffers from water pollution as most untreated wastewater from domestic and industrial activities is discharged into open water areas (*i.e.*, lakes and rivers). The study site was urban districts of Hanoi, the capital city of Vietnam. More than 90% of the households in the area use septic tanks that were poorly performed due to non-regular desludging (Harada *et al.*, 2008). Most domestic and industrial wastewater (approx. 620,000 m^3/day accounting for more than 90% of total discharge amount) is discharged into open water areas (*i.e.*, lakes and rivers) without treatment (MONRE, 2012). Among all drainage rivers of the city, To Lich river (*i.e.*, To Lich R.) which is 14.8 km long, 30-40 m wide and 3-4 m deep has the largest watershed area of 38.3 km^2 with the largest population of 892,102 (Dao *et al.*; HSO, 2010). The river starts its flow from introduction of West Lake water and ends it at Yen So lake where flown river water is drained to Red river by pumping (**Figure 4-1**).

Surveys

This chapter used the data from household water consumption and discharge survey in Chapter 3. These households were located in To Lich river watershed. In addition, we conducted a survey at To Lich river, where the wastewater is discharged into. Detailed methodologies in the study will be mentioned in the next section.

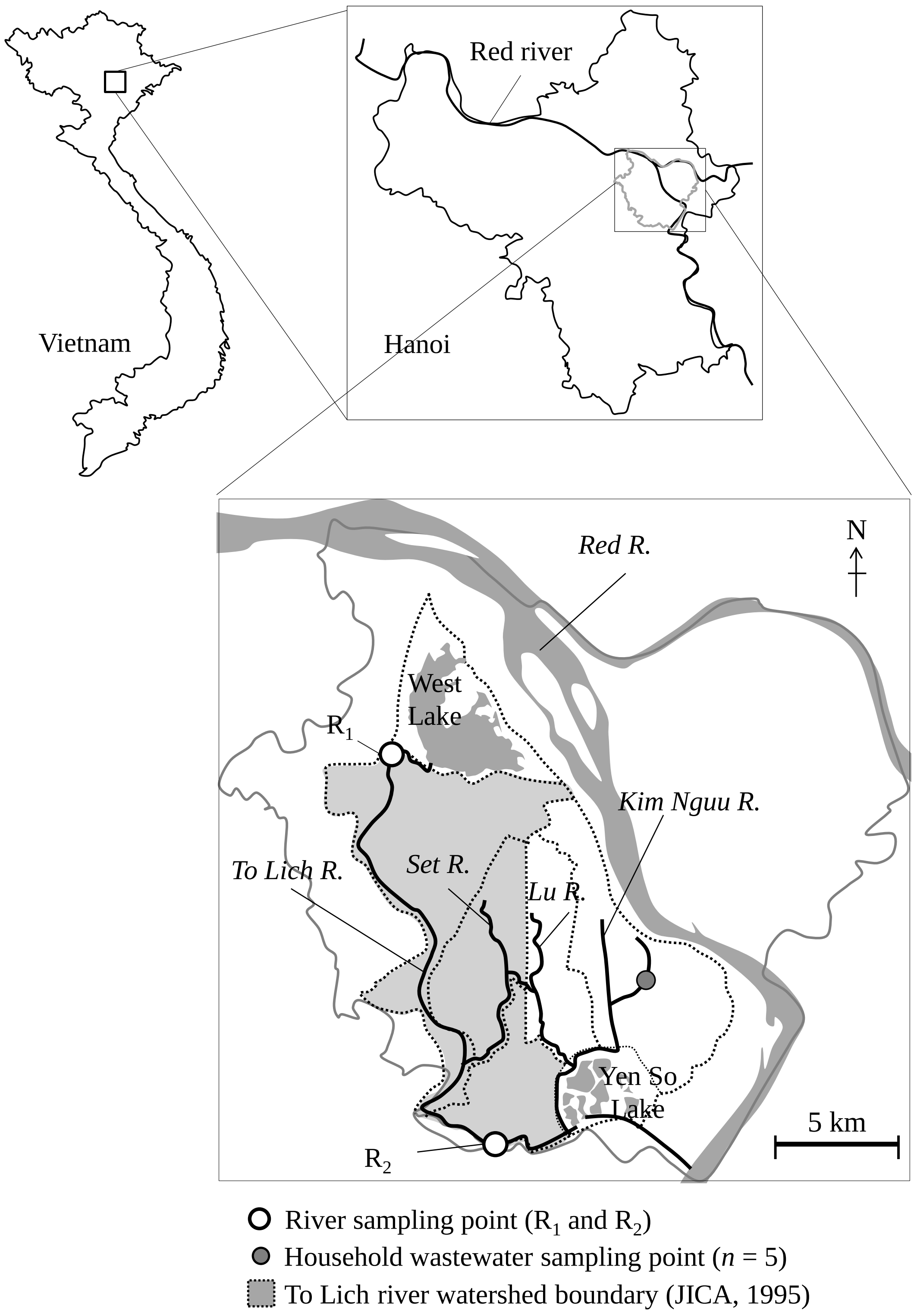

Figure 4-1 To Lich river watershed and sampling points

4.2.2 Household water consumption survey

A structured interview was conducted for 100 households in To Lich river watershed in December, 2012 as already mentioned in Chapter 3. The average water consumption amount obtained from the survey was 146±58 L/cap/day.

Ten modern apartment households out of 100 interviewed households were selected to record water consumption every hour within 48 hours (*i.e.*, two consecutive days) based on a water meter of each apartment (See in Chapter 3). The survey was conducted within 00:00 (Monday) - 24:00 (Tuesday), 00:00 (Tuesday) - 24:00 (Wednesday) and 00:00 (Wednesday) - 24:00 (Thursday) for four households, two households, and four households, respectively.

4.2.3 Household wastewater discharge survey

The survey was investigated at five households. These households discharged their wastewater to a nearby canal through a PVC pipe from a pit (approx. 30L), to which households disposed both of greywater and septic tank effluent.

A structured interview was conducted to collect the information about household size and water consumption amount of three consecutive months (September, October and November) measured by tap water-meter mentioned in water bills to estimate the average water consumption amount (L/cap/day). The discharged amount was measured every hour by graduated buckets during 24 hours. Wastewater was sampled every three-hour interval during the discharge measurement, starting at 0 AM by sampling method applied for all samples as follows. All the water discharged during 0 AM to 1 AM was collected and mixed carefully to obtain a composite sample representing for 0-1 AM. A part of the collected wastewater at six-hour intervals was filtered to make a soluble sample, and both of original (total) and soluble samples were analyzed for COD_{Cr}, BOD_5, SS, TKN, and TP. Particulate concentrations were calculated by the difference of the two above concentrations. The samples at three-hour intervals were analyzed for only COD_{Cr} and BOD_5. All of the parameters were analyzed by the Standard Methods (APHA, 2005). Analytical parameters were listed in **Table 3-3** in Chapter 3.

4.2.4 River survey

A river survey was carried out on weekdays near the inlet (R1) and near the outlet (R2) of To Lich river on January 21-22, 2013 and January 24-25, 2013, respectively (**Figure 4-1**). Distance between these two points was 14.2 km. It had not been rained two weeks before the river survey started. Information of river survey is listed in **Table 4-1**. The widths of the river at R1 and R2, which are 8 m and 30 m, were divided into five and six sub-sections, respectively. Flow velocities (cm/s) and depths (m) were measured by a flow-meter (AEM213-D) every hour at plural sub-sections along the river cross-section. River water was collected at four different durations on both days, which were 0 AM, 6 AM, 12 PM, and 6 PM to analyze COD_{Cr}, BOD_5, SS, TKN, and TP by the Standard Methods (APHA, 2005).

River flow measurement

Cross-sections of the river at the inlet and at the outlet of the watershed were divided into four and five sub-sections, respectively based on river width (UNEP/WHO, 1996). We measured river depth and flow velocity at each sub-section in a 48 hour-period by a flow meter (*i.e.*, AEM213-D, Japan) and took the average to obtain the flow rate patterns within 24 hours.

River water sampling and analysis

River water at the inlet and the outlet of the watershed was sampled every six hours during 48 hours. COD_{Cr}, BOD_5, SS, TKN, and TP were analyzed in the laboratory by the Standard Methods (APHA, 2005).

Table 4-1 Description of river survey at the inlet and the outlet of the watershed

Sampling point	Position		Sampling date
R1	A bridge at Hoang Quoc Viet street	N 21.04597 E 105.80530	0:00 January 21, 2013 – 24:00 January 22, 2013
R2	A bridge before Yen So pumping station	N 20.95104 E 105.83225	0:00 January 24, 2013 – 24:00 January 25, 2013

4.2.5 West Lake sampling and analysis

Two samples were obtained at West Lake on February 27, 2013 to analyze COD_{Cr}, BOD_5, SS, TKN, and TP by the Standard Methods (APHA, 2005). A part of the collected wastewater at six-hour intervals was filtered to make a soluble sample, and both of original (total) and soluble samples were analyzed for COD_{Cr}, BOD_5, SS, TKN, and TP. Particulate concentrations were calculated by the difference of the two above concentrations.

Unit pollution loading

Daily pollution loadings of household wastewater or river water were estimated as the product of hourly loadings within 24 hours. The hourly concentrations were interpolated based on the known concentrations at three-hour intervals or six-hour intervals depending on the parameters. The unit pollution loading was then calculated as follows.

$U_i = \sum_{t=1}^{24} C_i \times q_i$ **(Eq. 4-1)**

in which U_i is the unit loading from parameter i (g/cap/day); C_i is the concentration of parameter i in the wastewater at time t (g/m^3); q_i is the respective discharge rate at time t (m^3/hour).

Total pollution loading

Pollution loadings from wastewater of households in the watershed are estimated using **Equation 4-2**.

$\boldsymbol{L_{household,i} = U_i \times P \times 10^{-6}}$ **(Eq. 4-2)**

in which $L_{household,i}$ is the load of parameter i discharged from household wastewater (ton/day); U_i is the unit pollution load of parameter i discharged from household wastewater (g/cap/day); P is total population of To Lich river watershed (capita).

4.2.6 Pollution load accumulated at the river

Pollution load accumulated at the river is calculated as the difference between the loads at the inlet and at the outlet (**Equation 4-3**).

$$L_{river,i} = \left[\left(Q_{inlet} \times C_{inlet,i}\right) - \left(Q_{outlet} \times C_{outlet,i}\right)\right] \times 10^{-6} \times 8640 \quad \textbf{(Eq. 4-3)}$$

in which $L_{river,i}$ is the loads accumulated at the river of parameter i (ton/day); Q_{inlet} and Q_{outlet} are the flow-rates of To Lich river at the inlet and at the outlet of the watershed, respectively (m^3/s); $C_{inlet,i}$ and $C_{outlet,i}$ are the average concentrations of parameter i at the inlet and at the outlet of the watershed, respectively (g/m^3).

4.3 Results and Discussions

4.3.1 West Lake water quality

As shown in **Figure 4-2**, the West Lake was even polluted comparing to National technical regulation on surface water quality (QCVN 08:2008/BTNMT) possibly due to the discharge of domestic wastewater or the disposal of solid waste (MONRE, 2012). Comparing with the data in 2010 (MONRE, 2012), COD_{Cr} and BOD_5 in this survey increased by two times. It means the river is being polluted even its quality is good compared to other lakes in the city. Organic matter was dispersed in dissolved and particulate phase. TKN was mainly in soluble phase whereas TP was mainly in particulate one.

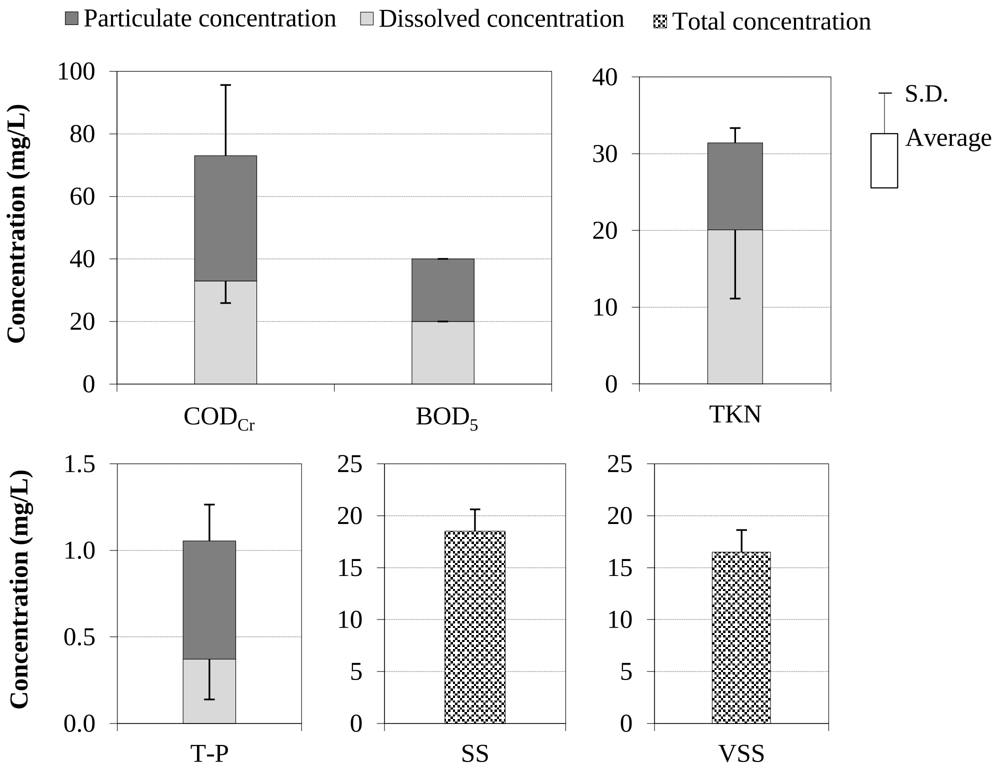

Figure 4-2 West Lake water quality with separated concentrations for COD_{Cr}, BOD_5, TKN, and TP (Date of sampling: February 27, 2013; sample number *n* = 2)

4.3.2 Household water consumption and discharge characteristics

Water consumption pattern

The average water consumption amount based on the calculation of water bills for 100 households was 146±58 L/cap/day. The relationship of 24-hour water consumption between the first and second day of 10 households in modern apartments is presented in **Figure 4-3**. It showed that hourly water consumption on the first day had a high relation to the data on the second day (R^2=0.97). That means each household had a routine of water consumption, which was almost same on weekdays. The average hourly water consumption shown in **Figure 4-4** indicated a low peak in the morning (4-10 AM) and a higher peak in the evening (5-11 PM), corresponded to before (7-8 AM) and after (4-5 PM) working/schooling hours, respectively. Almost no consumption was recorded at late night. It was investigated by Busser *et al*. (2006) that residents in Hanoi prefer to take a shower and do a laundry in the evening, and toilet use happens mostly in the morning. The study also indicated a peak of water consumption in the evening, similarly to our observation in this study (5-11 PM).

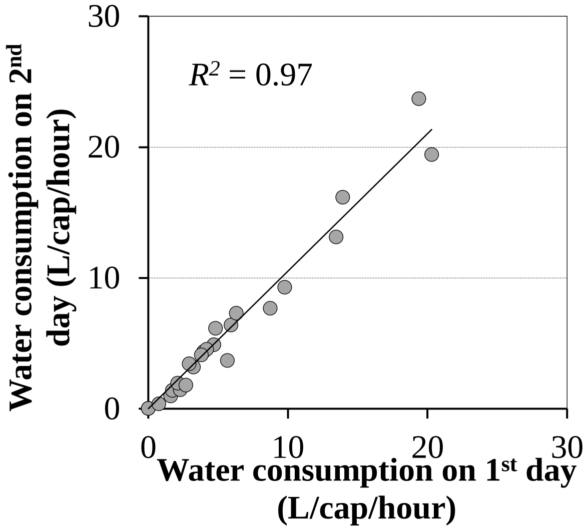

Figure 4-3 Relationship of 24-hour water consumption (L/cap/hour) between the first and second days.

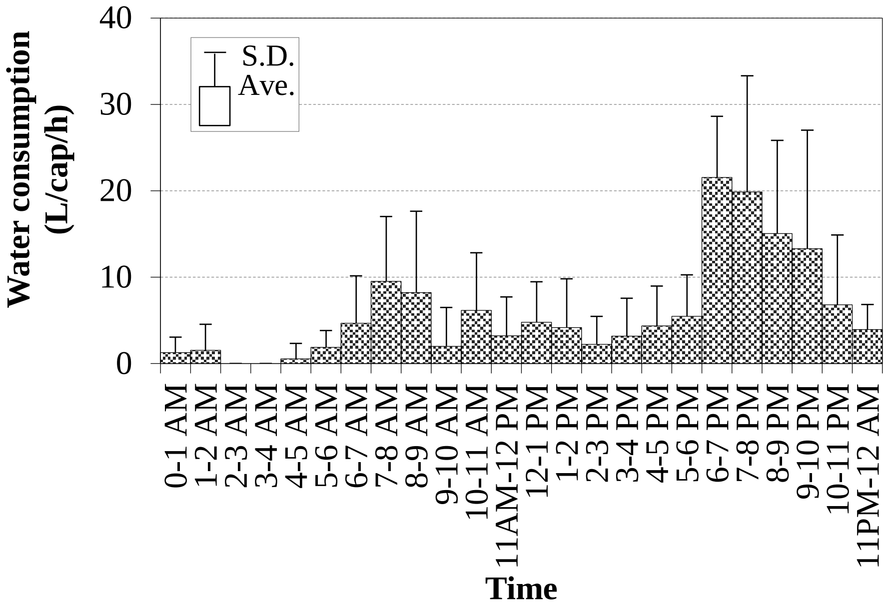

Figure 4-4 Average hourly-per-capita water consumption for 10 households living in modern apartments.

Water discharge characteristics

Hourly discharge amounts of five households are shown in **Figure 4-5**. The discharge pattern was more evenly distributed than the consumption pattern may be due to the different water-consuming lifestyles or function of the pit that makes the discharge amount more equalized. In **Figure 4-6**, water consumption of three months and water discharge on the sampling day for five households were plotted versus each other, indicating that water discharge amount on the sampling day was quite similar to average water consumption amount. The discharge amount was slightly lower than the consumption amount, which may be caused by the function of the pit or water used for the activities such as bonsai watering did not go out as discharge.

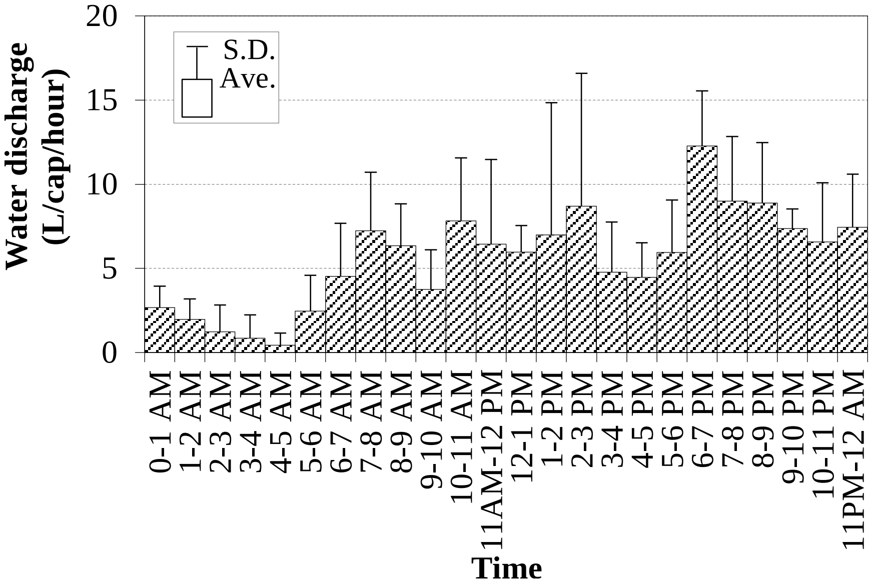

Figure 4-5 Average hourly water discharge from five households.

At-source wastewater quality

Household wastewater concentration pattern is illustrated in **Figure 4-7**. The highest concentrations were found at 12-1 PM as the wastewater was little diluted due to low water consumption at this duration. The wastewater concentrations then sharply decreased at 6-7 PM which can be understood as greywater from bathing and laundry were much diluted by the rapid increase in water consumption. During night time (0-1

AM), the wastewater remained in plumbing system was still gradually discharged. Average COD_{Cr}, BOD_5, TKN, and TP concentrations were 471 mg/L, 225 mg/L, 57 mg/L, and 8 mg/L, respectively. The suspended solids concentration (80 mg/L) was very low. The ratio of particulate COD_{Cr} to dissolved COD_{Cr} (0.58) indicates that organic matter was mainly found in soluble. Most BOD_5 and TKN at different sampling durations were also found to appear in soluble phase whereas a large part of TP was in solid phase.

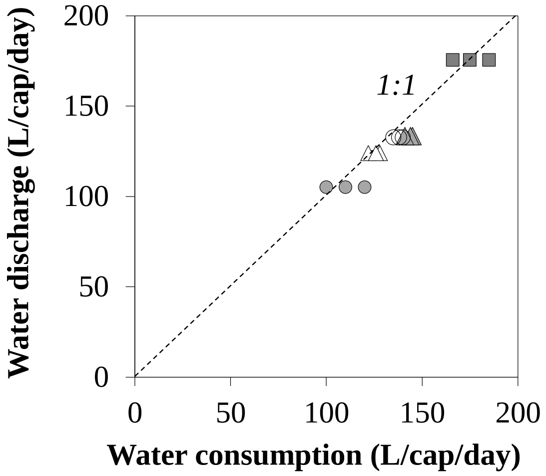

Figure 4-6 Relationship between water consumption of three months and water discharge on sampling day for five households.

4.3.3 Unit pollution load from household wastewater

Unit pollution loadings from household wastewater for COD_{Cr}, BOD_5, TKN, TP, SS were calculated based on **Eq. 4-1** (**Table 4-2**). The results in this study were higher than those in previous study (Busser *et al.*, 2006). In the study of Busser *et al.* (2006), the wastewater sample was taken one time at each point of discharge such as bathing, laundry, cooking, and toilet use. Our loading data (g/cap/day) provided more detailed in every-hour loading. The data had a wide range as wastewater composition and water consumption vary among the households. The wastewater is composed of septic tank effluent and greywater after a small pit, which are dependent on eating habits, toilet papers, septic tank performance, chemical uses, age distribution of household members, their lifestyles, *etc*. Substances in the wastewater are nutrients (nitrogen and phosphorus), organic compounds, grease, solids, heavy metals which come from detergents, soaps, shampoos, hair, oil from kitchen, *etc*.

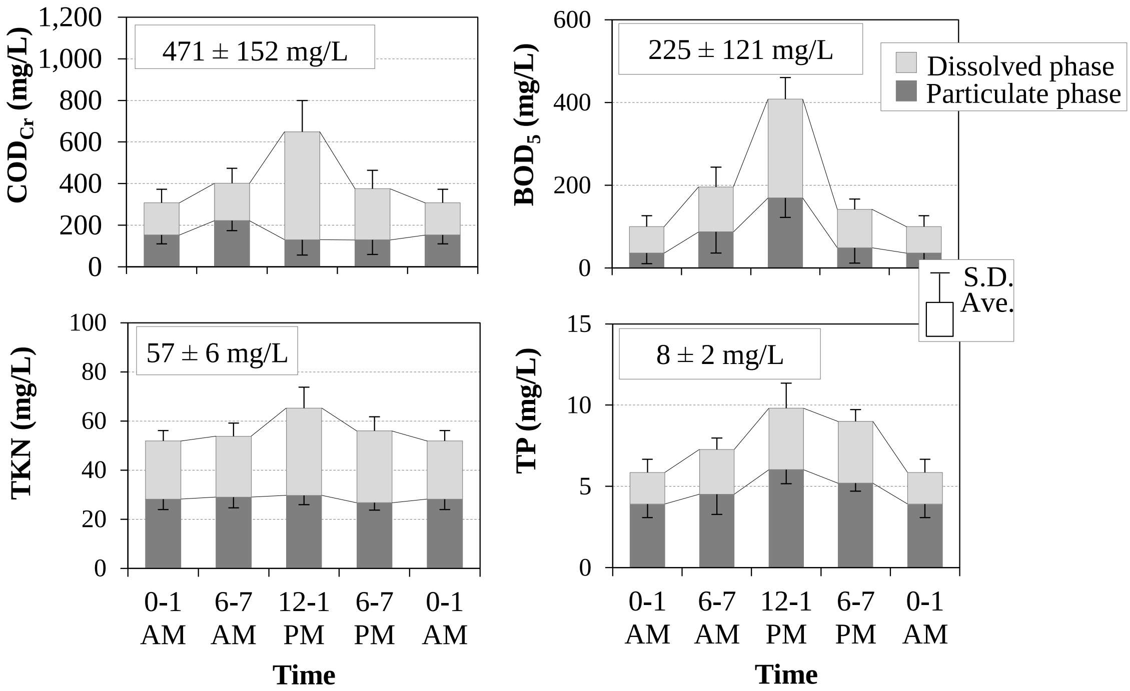

Figure 4-7 Household wastewater concentration patterns for five households in dissolved and particulate phase. Average±S.D. are given on the chart.

Hourly pollution loadings from household wastewater are presented in **Figure 4-8**. The loadings during 10 AM-4 PM showed the highest values, which might come from septic tank effluent due to high frequent use of toilets. The second highest loadings were observed during 6-10 PM when not only toilet use but also bathing/showering and laundry were the main activities. The wastewater was discharged directly into local open canal and may deteriorate the receiving waters. In fact, the discharged wastewater polluted the receiving canal with foul odor and dark color. From this point, in addition to current septic tank use, further treatment of household wastewater is essential to protect water bodies and prevent potential health by exposure to ambient water.

Table 4-2 Unit pollution loading from household wastewater compared to other data

Item	Average	S.D.	Hanoi (Busser *et al.*, 2006)	Japan (IDI-Japan, 2004)
COD_{Cr}	65.6	10.4	55.0	27.0*
BOD_5	31.9	5.3		58.0
TKN	7.6	0.9	6.3	11.0**
TP	1.1	0.1	1.1	1.3
SS	11.6	5.1		45.0

Note: * COD_{Mn}, **T-N

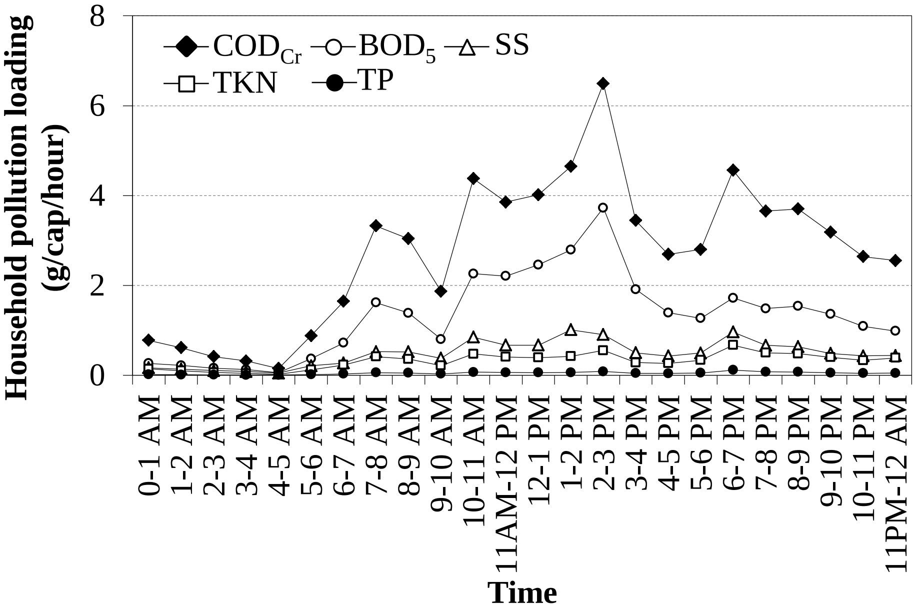

Figure 4-8 Hourly pollution loading from household wastewater

4.3.4 To Lich river characteristics

River flow-rate

Flow-rate patterns of To Lich river at its intake from West lake and at its outlet within two consecutive days are presented in **Figure 4-9**. The flow-rate at the inlet indicated the highest rates in the evening (5-11 PM), the second highest rates in the daytime (10 AM-3 PM) and the lowest rates in the early morning (3-7 AM). This trend is quite similar to the trend of household water consumption but the peaks were more delayed. It implies that the river flow was affected by household discharge even near the inlet and the wastewater at upstream needed 31 hours for running to the outlet. The flow-rate near the outlet, therefore, showed less variable and more delayed compared to that at the inlet. The flow-rate at the outlet showed less variable and more delayed compared to that at the inlet. These can be explained as peaks of water discharge at individual households were mixed in the river and water discharge in upstream needed time for running to the outlet. Another the reason can be explained as the survey at the inlet and the outlet were conducted on different days. The flow-rate at the outlet (624,976 m^3/day) increased by about 30 times compared to the flow-rate in the inlet (21,238 m^3/day). As the survey was conducted in dry season and there had not been a rain at least two weeks before the river survey started, the increased water amount can be regarded as the total wastewater amount from the watershed.

River water quality

As shown in **Figure 4-10**, To Lich river was seriously polluted at its intake from West lake right after the river flow received the discharge from the watershed. Average concentrations at the outlet were not much higher than those at the inlet, except SS concentration. It showed that the river received the similar wastewater at the inlet and the outlet. SS concentration at the outlet (88 mg/L) nearly doubled the concentration at the inlet (49 mg/L), indicating the accumulation of solid matter in the downstream during river running. A similar trend with the peaks at 12-1 PM in river quality concentrations at the inlet and household wastewater concentrations again confirmed that household discharge affected river flow at the inlet and the discharge was mixed and dispersed in the river. Therefore, concentrations at the outlet were less variable.

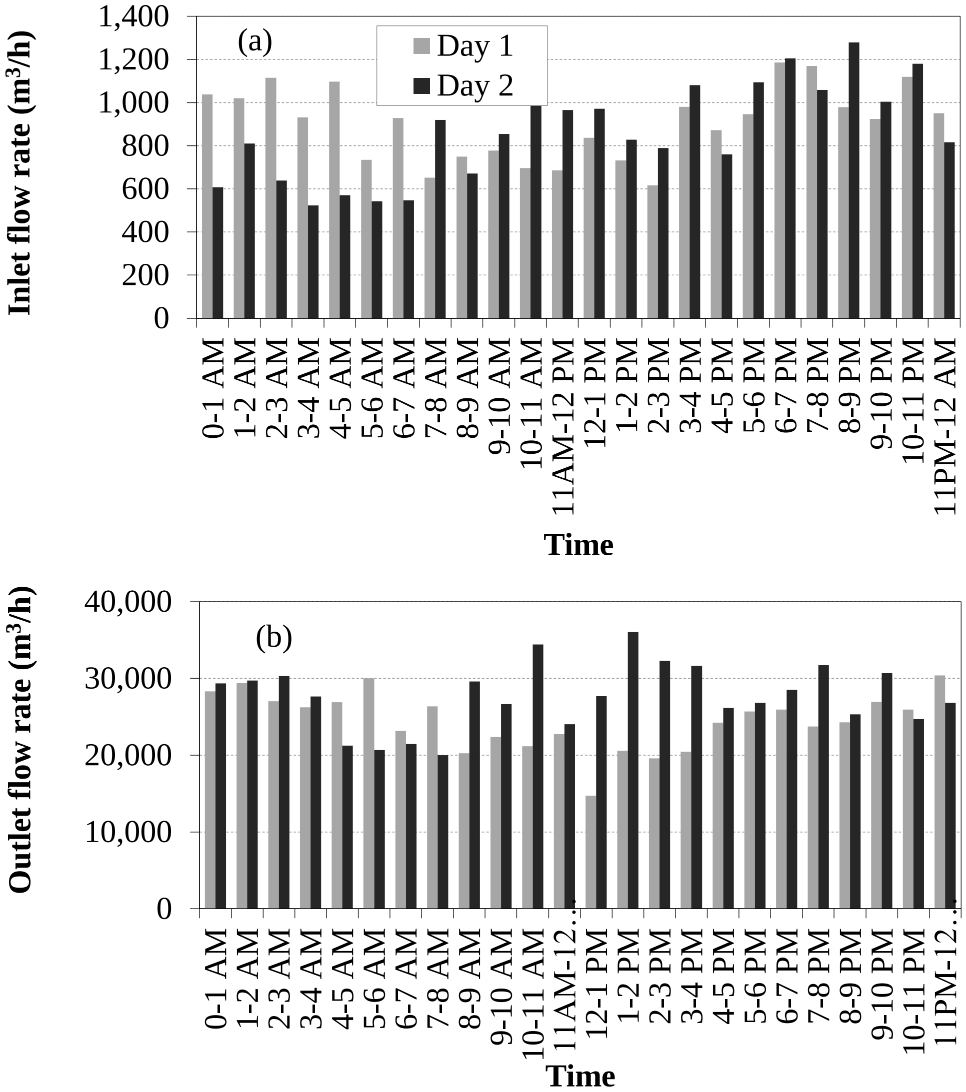

Figure 4-9 To Lich river flow-rates: (a) at the inlet as its intake from West lake (January 21st - 22nd, 2013); (b) at its outlet (January 24th - 25th, 2013).

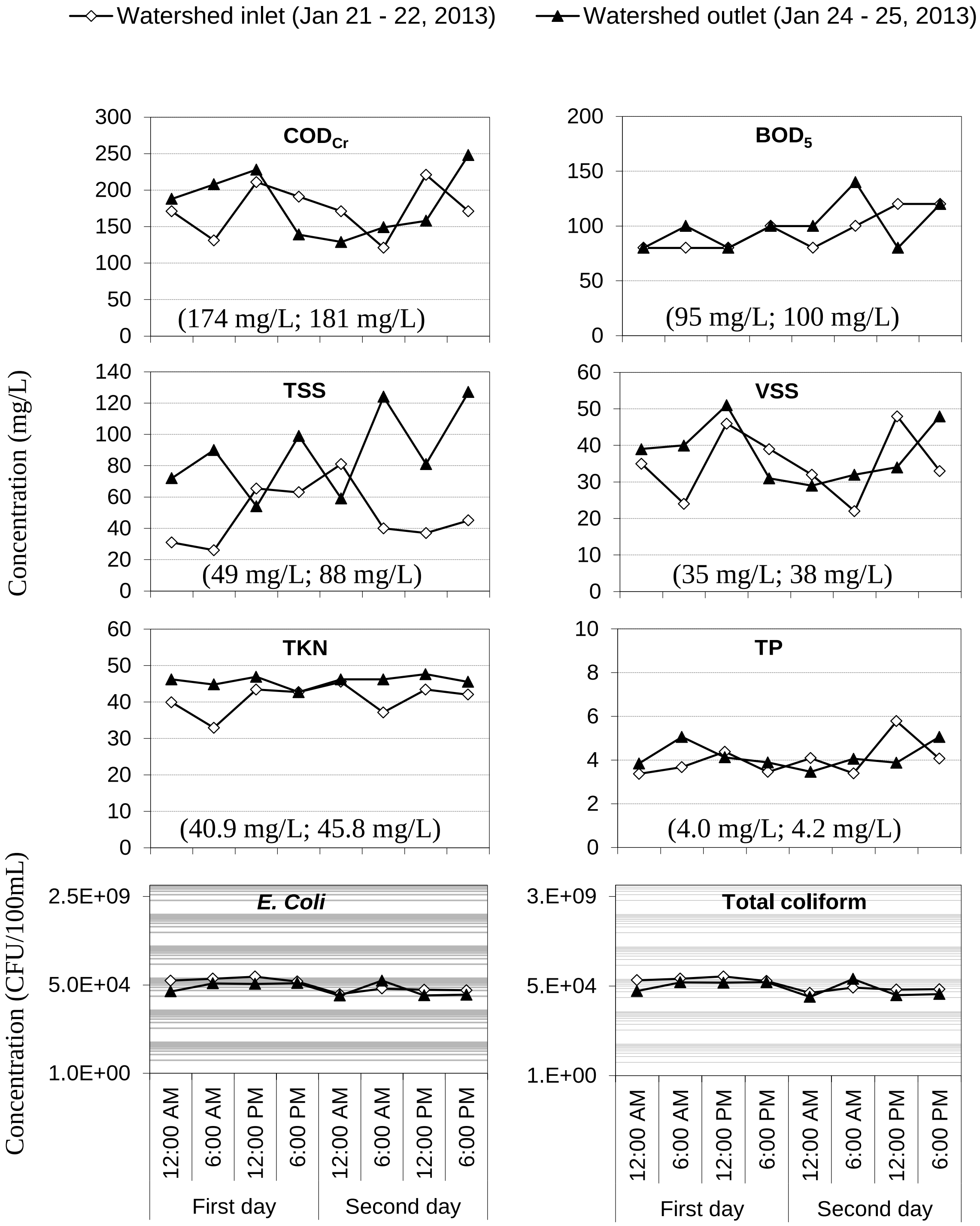

Figure 4-10 To Lich river quality at the inlet (January 21st - 22nd, 2013) and the outlet of its watershed (January 24th - 25th, 2013) throughout 48 hours continuously. Average concentrations (inlet, outlet) are given on the chart.

4.3.5 Pollution loads from household wastewater

Discharge amount of household wastewater was calculated as 130,247 m^3/day based on average daily water consumption, which accounted for 22% of total discharge to the river (603,738 m^3/day). **Figure 4-11** presents estimated loads from household wastewater and that accumulated in the river water. The highest peaks of household loading were found at 5-10 PM when the highest peaks of water consumption were also recorded. Although household wastewater loadings were fluctuated showing the observed peaks during day-time (9 AM-4 PM), the loadings in river water were not much fluctuated as the discharge from households needed time to appear in the river.

The households contributed a large proportion of organic pollution to the river. The estimated COD_{Cr} and BOD_5 loadings were 58.5 ton/day and 28.4 ton/day, comprising about 53.5% and 47.0% of those loadings from the watershed, respectively. The BOD_5 concentration in household wastewater (225 mg/L) was higher than that in river water at the inlet (95 mg/L) and at the outlet (100 mg/L) of the watershed because the wastewater had been changed by in-sewer processes and much diluted by other water before it appeared in the river. However, the households were still the big contributor to organic pollution. The loadings of TKN (6.8 ton/day) and TP (1.0 ton/day) from household wastewater contributed 24.5% and 40.0% to those loadings in the river, respectively. Although TP in household wastewater contained a large part of solid matter, which settled after discharge from households, it was still the big contributor to TP loading in the river. On the other hand, TKN in household wastewater (57 mg/L) was mainly in the form of dissolved matter and denitrification might not be effectively occurred while the wastewater was flowing to the river. The wastewater was much diluted but the TKN concentrations in river water was still high (40.9 mg/L at the inlet and 45.8 mg/L at the outlet), which indicates that a large part of TKN from other sources entered the river as well. The SS concentration in household wastewater was low (80 mg/L) and SS loading was then contributed 19.1% to river water. The big SS loading in the river (54 ton/day) can be explained by the settling effect and accumulation in the downstream as suspended solids concentration is almost governed by sedimentation process.

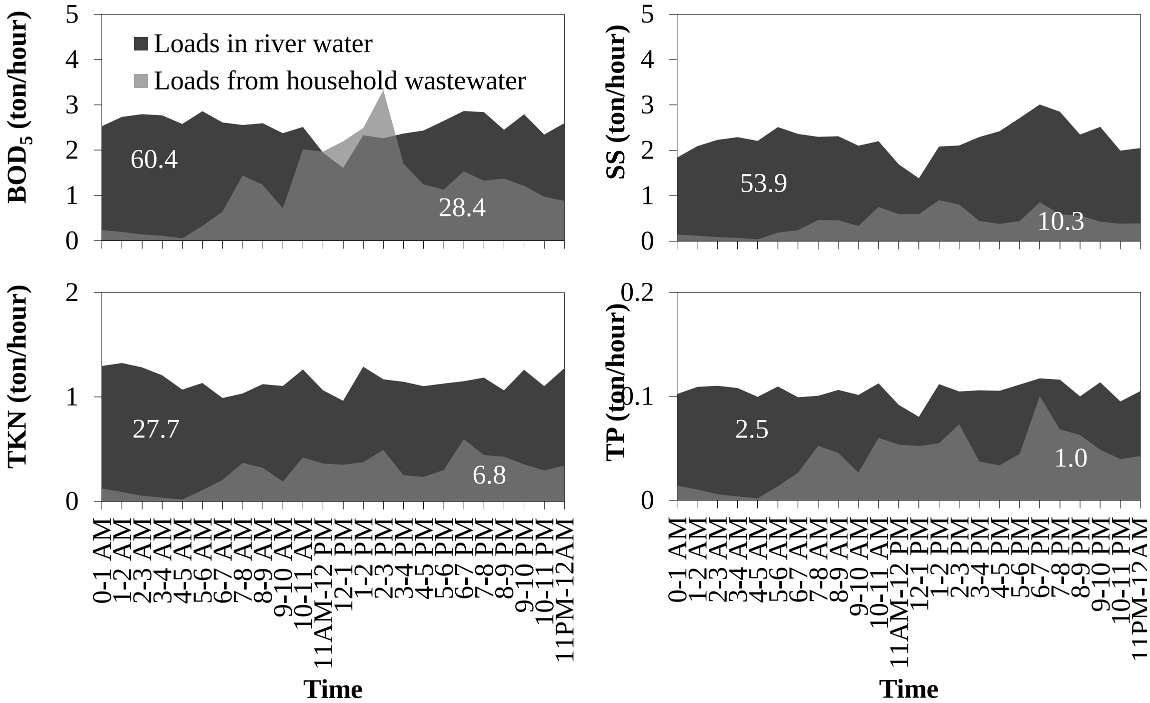

Figure 4-11 Estimated pollution loading from household wastewater and the loading accumulated in the river water. Average loadings (ton/day) are given on the chart.

Unit pollution loadings from the watershed (kg/ha/day and kg/cap/day) in terms of COD_{Cr}, BOD_5, SS, TKN, and TP were estimated (**Table 4-3**). The data can be used for the management of an urban watershed.

Table 4-3 Pollution loading from household wastewater compared to loading from the watershed to the river

Item	Loading from households (ton/day)	Loading to river (ton/day)			Unit loading from watershed	
		Inlet	Outlet	Accumulation	kg/ha/day	g/cap/day
COD_{Cr}	58.5	3.7	113.0	109.3	28.5	122.5
BOD_5	28.4	2.0	62.4	60.4	15.8	67.7
SS	10.3	1.0	55.0	54.0	14.1	60.5
TKN	6.8	0.9	28.6	27.7	7.2	31.1
TP	1.0	0.1	2.6	2.5	0.7	2.8

4.4 Conclusions

Pollution loading from household wastewater was studied based on the target watershed in urban areas of Hanoi, Vietnam where the septic tanks are the most popular on-site facilities for the pre-treatment of toilet waste. The large parts of COD_{Cr}, BOD_5, and TKN in household wastewater were found to appear in soluble matter whereas that of TP was in particulate one. The loading trend was detected, showing the biggest peak of loading and hourly water discharge happened at the same duration (9 AM-4 PM). It was estimated that the household discharge accounted for only 21% of total discharge amount into the river but contributed large parts of BOD_5 (47.0%) and TP (40.0%) pollution possibly due to septic tank discharge. Effluent from improperly managed septic tanks is discharged directly into local rivers which are drainage canals conveying wastewater to treatment plants. The open sewage collection may cause potential health risk because of exposure to polluted ambient water. This chapter investigated the big contribution of households to river pollution and suggested that proper management of the septic tanks should be given attention to protect water environment and public health. The obtained information provides a comprehensive understanding for pollution controlling and development of wastewater management strategy in urban areas.

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Publication

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Proceeding

Pham N. A., Fujii S., Harada H., Tanaka S. , Nguyen P. H. L., Huynh T. H. (2014). Study on household pollution loading and evaluation of septic tanks' function. Proceeding of the 13th International Water Association (IWA) specialist conference on watershed and river basin management (September, 9-14), San Francisco, USA.

Presentation

Pham N. A., Harada H., Fujii S., Nguyen P. H. L., Huynh T. H., Tanaka S. (2013). To Lich river pollution loads and its household wastewater contribution. *International Forum for Green Technology Management*, September 5-6, Hanoi, Vietnam.

Chapter 5 Septic tank pollution loads and accumulated sludge characteristics

5.1 Introduction

Although it is recognized that septic tanks cannot produce high quality effluent without trench fields (Tchobanoglous and Burton, 2003), septic tanks in Vietnam generally do not have trench fields for effluent treatment. Septic tanks' effluents are discharged directly into sewers; but the sewers then discharge wastewater into open water areas due to limited wastewater treatment capacity.

Septic tanks serve for pretreatment of blackwater before discharging into open water areas but management of the septic tanks is at low level in Hanoi. No desludging even after long operating period causes excessive sludge accumulation inside the septic tanks. The excessive accumulation of sludge and scum reduces settling volume and diminishes the treatment efficiency by carry-over of sludge and scum into effluent. As wastewater generated from households is mostly discharged into open water areas, the city severely suffers water pollution.

It was proposed by Harada *et al*. (2008) that annual desludging can eliminate 72.8% COD_{Cr} and 24.5% SS loads from septic tanks in urban Hanoi. At the same time, regular and frequent desludging leads to increase in volume of collected septage, which should be properly treated. Because expansion of sewerage systems requires long-term duration, septic tanks are still the most popular on-site treatment facilities in future decades. For the improvement of environmental and sanitary condition, it is necessary to develop desludging frequency and appropriate treatment of septage.

However, sludge accumulation rate, the necessary information for adequate septic tank and desludging frequency design is not sufficient (Chidozie and Jonah, 2012). Most available data were investigated in developed countries where the septic tanks mainly receive greywater and blackwater. In addition, sludge accumulation varied widely depending on septic tank condition.

Since the establishment of sewerage system required decades even for urban centers, understanding of pollution loads from the septic tanks are essential especially in the case of sub-urban areas.

This chapter aims at estimating pollution loads from septic tanks and sludge accumulation and characteristics in the septic tanks based on a case study in sub-urban areas of Hanoi, Vietnam.

5.2 Materials and Methods

5.2.1 Study site

The study site was Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi which was composed of nearly 1,500 households. The hamlet locates about 20 km in the West of Hanoi center (**Figure 5-1**). Previously, the area belonged to Ha Tay province and local people did farming and livestock breeding to earn their main incomes. After an expansion of Hanoi in 2008, the area became a sub-urban of Hanoi city and agricultural land was reformed. Until now, a large amount of local households runs a house lease or performs hired labor in surrounding areas instead of agricultural activities to earn their main incomes. Only a few numbers of households are still raising pigs and chickens and growing crops to serve themselves.

Similarly to other sub-urban areas of Hanoi where public water supply is not covered, harvesting rainwater in rainy season is a traditional way providing water for cooking and drinking for a whole year use. The water for other daily activities such as bathing, toilet flushing, washing, *etc*. mainly comes from underground water extracted from private drilled wells after simple treatment. The area has four public dug wells where local residents often went and took water but this tradition has been changed as most households have private drilled well.

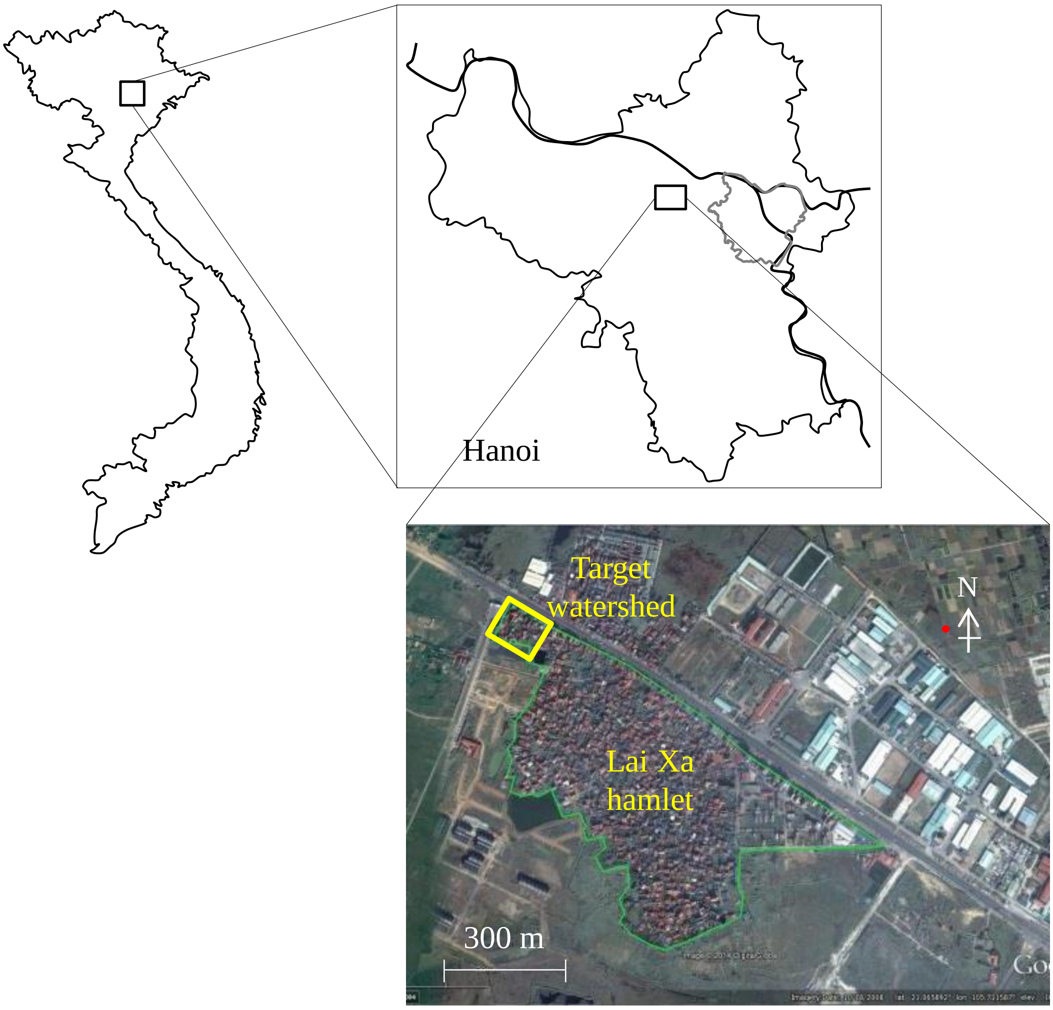


Figure 5-1 Map of the study site: Lai Xa hamlet and a target drainage watershed.

5.2.2 Drainage watershed

We selected a drainage watershed including 62 households (240 people) where no livestock breeding exists to avoid the effect of this activity on wastewater discharge. There was agricultural land in the watershed where the households were growing crops of vegetables to serve themselves. Greywater and septic tank effluent after a pit were discharged into drainage canals, and then wastewater from these two canals was combined (**Figure 5-2**).

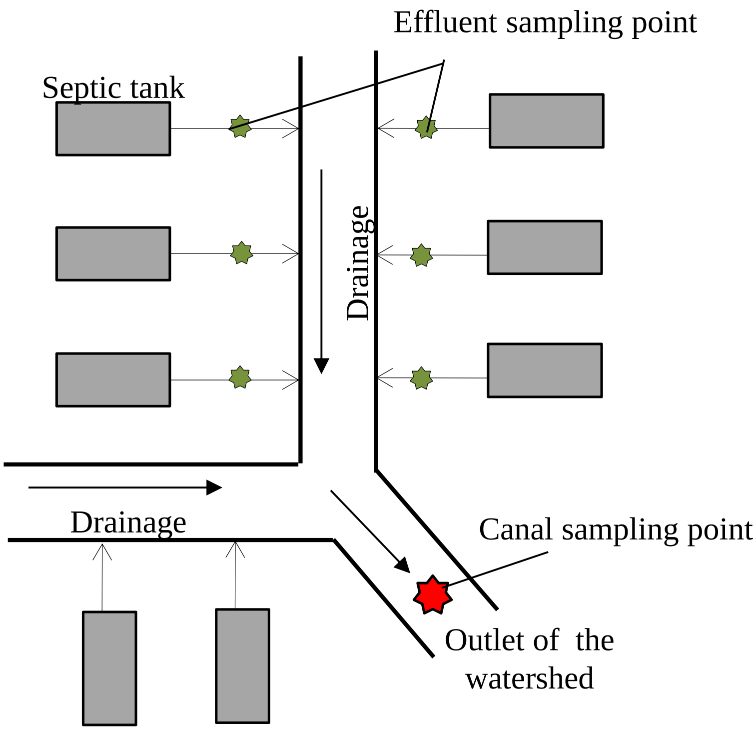


Figure 5-2 Discharge of septic tank effluent into the drainage canal

5.2.3 Description of the surveys

The study included all surveys as described in **Figure 5-3**. A structured interview was conducted to 100 households living in the hamlet to collect necessary information and check the possibility for sampling effluent and septage. Pollution loads survey was then conducted at the outlet of the drainage watershed, including flow measurement and canal water and analysis. After pollution loads survey had been finished, septic tank survey was conducted for 46 septic tanks, of which 21 tanks are located inside the target drainage watershed. For each tank, effluent was sampling after effluent is confirmed by flushing toilet. Right after the septic tank had been accessed for desludging, the depth of sludge inside septic tank was measured by specific instruments. Then, desludging was conducted by a vacuum truck and septage sample was obtained by composite sampling while the vacuum truck was discharging septage to a designate area. Ten septic tanks were selected among the 46 tanks to be desludged again after two to three days to obtain fresh septage samples. Detailed information of each survey will be mentioned in the next sections.

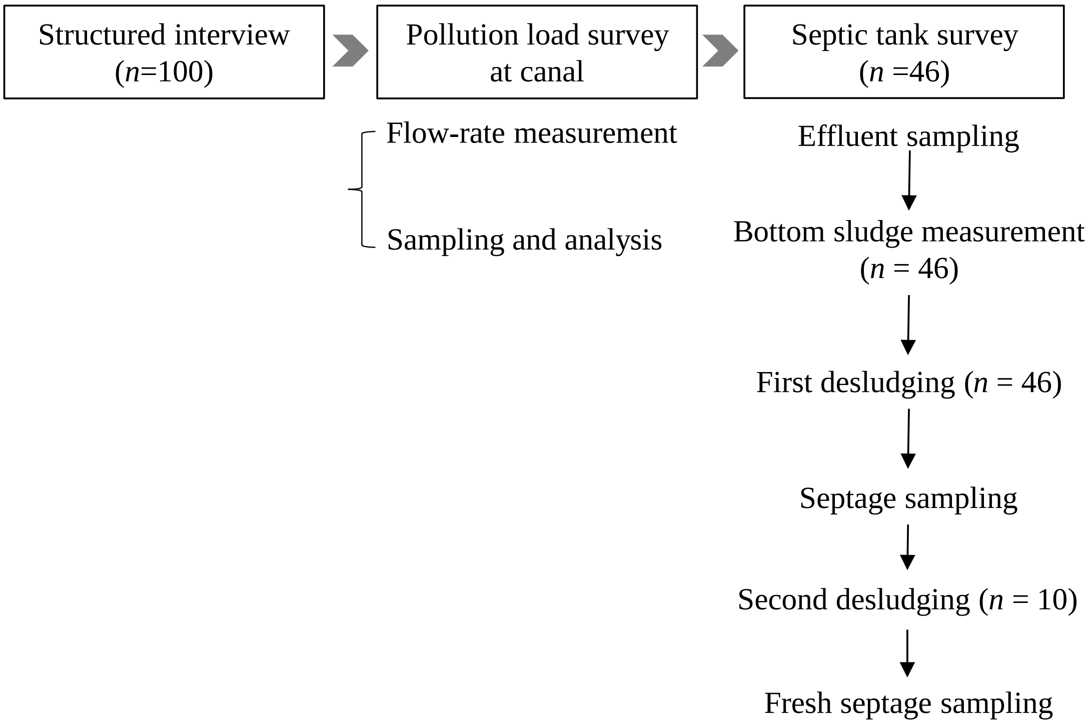


Figure 5-3 Sequence of all surveys conducted for households in the hamlet.

5.2.4 Structured interview

A structured interview was conducted for 100 households in the watershed to collect information about household attributes, toilets, septic tank operation and maintenance. Detailed contents of the interview are listed in **Table 5-1**. Meanwhile, we also checked the discharging location of wastewater in every house to confirm possibility of sampling.

Table 5-1 Contents of structured interview in Lai Xa hamlet

Item	Content
Household attributions	Number of members, main occupation
Toilet facility	Cistern-flush toilet, pour-flush toilet
	Flushing volume
Septic tank structure	Shape, number of chambers, material, construction year
	Size (length, width, depth)
Desludging condition	How many times, when was the latest desludging
Chemical use	

5.2.5 Volume of water discharged from toilet

The previous survey in Hanoi about frequency of toilet use throughout a day showed that each person flushes toilet 5 times/day in the house. It can be understood that amount of septic tank effluent by every flushing is equal to flushing volume of the toilet. All of the households in the watershed were equipped with cistern-flush toilet.

Total volume of water discharged from septic tank (*i.e.* septic tank effluent) all residents living in the watershed can be estimated by a following equation (**Equation 5-1**).

$$Q_{septic\ tank} = F_{toilet} \times V_{flush} \times P \times 10^{-3} \quad (\textbf{Eq. 5-1})$$

in which $Q_{septic\ tank}$ is the volume of septic tank effluent in the watershed (m^3/day); F_{toilet} is the number of toilet flushing by each resident (times/cap/day); V_{flush} is the volume of flushing water from cistern-flush toilets (6L/time); P is the population of the watershed (cap).

5.2.6 Pollution loads from septic tanks

Septic tank effluent sampling and analysis

The effluents of 46 septic tanks located in the hamlet were sampled. Twenty-one septic tanks, out of the 46 tanks are located inside the target watershed. Before the sampling was carried out for each septic tank, a toilet connected to the tank had been flushed several times to confirm the discharge of the effluent. After the confirmation had been done, the effluent was sampled and measured pH, E.C, and T^0 onsite. A sample bottle was preserved and transported to laboratory to analyze BOD_5, COD_{Cr}, TKN, TP, SS, VSS, Cl^-, and Total coliform by the Standard Methods (APHA, 2005).

Calculated pollution loads from septic tanks

Pollution loads of septic tanks in the watershed were estimated based on observed effluent quality of 46 septic tanks.

$L_{septic\ tank,i} = C_{effluent,i} \times Q_{septic\ tank} \times 10^{-3}$ (**Eq. 5-2**)

in which $L_{septic\ tank,i}$ is the loads from septic tanks of parameter i (kg/day); $C_{effluent,i}$ is the average concentration of parameter i in septic tank effluent (g/m^3); $Q_{septic\ tank}$ (m^3/day) is the volume of septic tank effluent assuming that each flushing volume is 6L and each person uses toilet 5 times (from Chapter 3).

5.2.7 Pollution loads at the outlet of the watershed

Canal survey

A canal survey, consisted of flow measurement and water quality analysis, was conducted within two consecutive days (January 8^{th} - 9^{th}, 2014) at the outlet of the watershed. We measured the canal flow-rate by a weir designed by "Thel-mar", the name of a manufacture (**Figure 5-4**). Because the weir consists of a rectangular weir and triangular weir, it is called a combined compound weir, which is a rectangular weir with a symmetrical 90^o V-notch in the center of the crest.

This combined weir is manufactured by a thin, vertical transparent slab of plastic, and is placed in the center of a metal frame with a rubber airtight seal that provides slight flexibility. To install this weir on the site, the weir is placed into a PVC pipe and then installed perpendicular to the flow using clay (**Figure 5-5**).

The canal flow-rate was recorded continuously every 15 minutes to calculate an average of each one hour within two days. Canal water was sampled at 0AM, 4AM, 6AM, 8AM, 10AM, 12PM, 3PM, 5PM, 6PM, 7PM, 8PM, and 10PM on each day to measure pH, E.C., T^o on-site. A sample was contained in a bottle, preserved, and transported to laboratory to analyze BOD_5, COD_{Cr}, TKN, TP, SS, VSS, Cl^-, and Total coliform by the Standard Methods (APHA, 2005).

Figure 5-4 A V-notch weir by “Thel-mar”.

Figure 5-5 Installation of the weir for flow-rate measurement.

Calculated pollution loads at the outlet of the watershed

Pollution loads at the canal was calculated based on the below equation.

$L_{canal,i} = C_{canal,i} \times Q_{canal} \times 10^{-3}$ (**Eq. 5-3**)

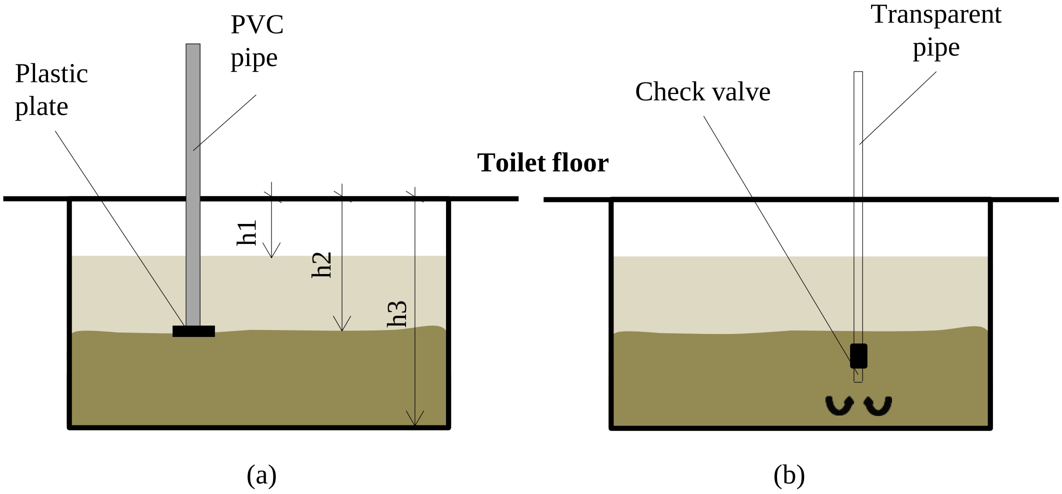
in which $L_{canal,i}$ is the loads at the canal of parameter i (kg/day); $C_{canal,i}$ is the average concentration of parameter i in canal wastewater (g/m^3); Q_{canal} is the volume of wastewater the canal measured by the weir (m^3/day).

5.2.8 Accumulated sludge characteristics

Septage contains liquid and solid (*i.e.*, bottom sludge) layers. Depth of the septage inside septic tanks was measured by two specific instruments right after the septic tank had been accessed for desludging (**Figure 5-6**). Since the septic tank does not have an accessing port, a worker had to drill a hole on the top of septic tank, which is normally toilet floor for the access of suction pipe. Size of the hole is about 10-12 cm. It was confirmed that there is no contradiction between the depths of each layer of septage measured by two instruments.

Bottom sludge measurement

Instrument A is a PVC pipe with measurement unit attached with a plastic plate (**Figure 5-6(a)**). The pipe was vertically put into the tank through a hole until it reaches the liquid surface, the sludge surface, and finally the septic tank bottom. The depth from the top of the septic tank to liquid surface regardless thickness of toilet floor was noted (h1). The depth from the septic tank to sludge surface (h2) and septic tank bottom (h3) were noted, respectively.



- h1: depth to septage surface
- h2: depth to solid layer
- h3: depth to septic tank bottom

Figure 5-6 Description of two methods to measure sludge depth inside septic tank: (a) instrument A; (b) instrument B.

Instrument B is an acrylic pipe (*i.e.*, transparent pipe) with measurement unit and equipped with a check valve (**Figure 5-7**). The check valve is possible to let a flow come into the pipe by only one way. In this case, the flow is possible to come into the pipe from the bottom. When the pipe was gradually and slowly put into the septic tank through a drilled hole, the check valve opens and septage come into the pipe. After the pipe reached septic tank bottom, the pipe was slightly lifted up and the valve was closed due to the pressure caused by weight of septage inside the pipe. The pipe was then taken out of the tank slowly. The transparency of the pipe allowed seeing clearly the separated layers of solid and liquid of the septage. The depth of septage layer, the liquid layer, and solid layer were noted, respectively. The results must be not contradicted the results obtained by instrument A.

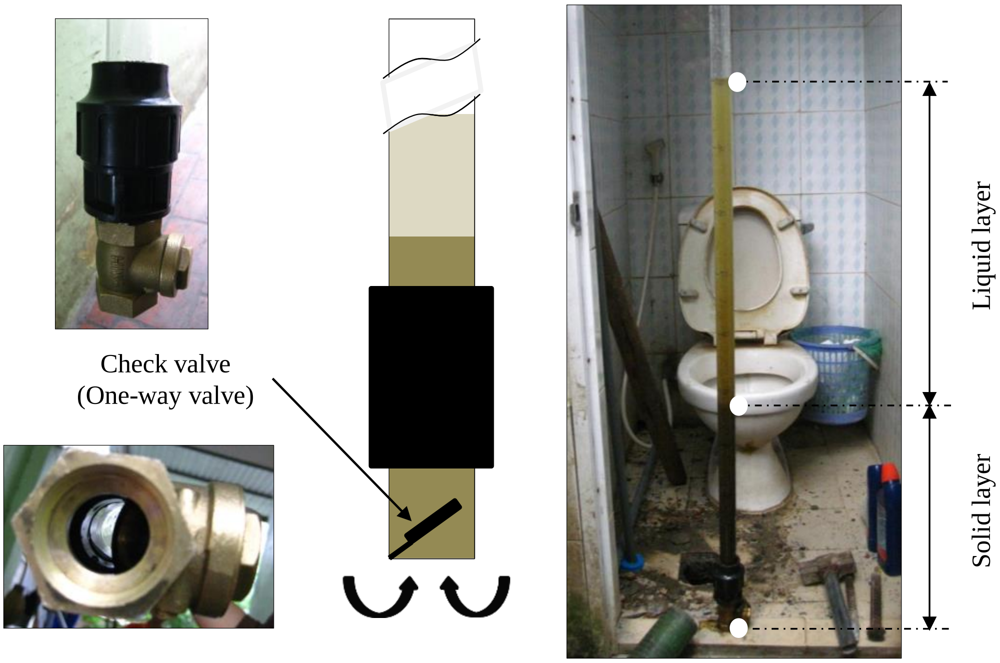


Figure 5-7 Description of sludge depth measurement using instrument B

Bottom sludge accumulation rate

Desludging was conducted for 46 septic tanks by vacuum trucks. The depth and thickness of liquid and solid layers of septage were measured in the first chambers of the septic tanks by specific instruments. Size of the first chamber was two-third of septic tank's area. The length and width of the tanks were collected through structured interview. Bottom sludge accumulation rate in the first chamber was estimated by **Equation 5-4**.

$$R_{accumulated} = \frac{L_{tank} \times W_{tank} \times H_{sludge}}{N \times I_{desludging} \times 365} \times 10^{-3} \quad \textbf{(Eq. 5-4)}$$

in which $R_{accumulated}$ is the sludge accumulation rate in the first chamber of the septic tank (L/cap/day); L_{tank} is the length of the first chamber of the septic tank (m); W_{tank} is the width of the first chamber of the septic tank; H_{sludge} is the thickness of bottom sludge in the first chamber measured by specific instruments; *N* is number of septic tank users (cap), $I_{desludging}$ is the desludging interval (year).

Septage sampling and analysis

Septage sampling was conducted for 46 septic tanks. Two sampling methods were compared. A transparent pipe (*i.e.*, instrument B) with a bottom stopper was installed into a septic tank chamber vertically, and sludge was collected (*i.e.*, cylinder sampling). Also, sludge was collected by a suction truck. A representative septage sample for each septic tank was obtained by composite sampling. Each liter of septage was collected while the vacuum truck was discharging (including t=0) and then mixed carefully to obtain a representative sample (*i.e.*, composite sampling).

Out of 46 septic tanks, eight were again desludged two days after the first desludging to obtain the septage without significant composition change after generation (*i.e.*, fresh septage). All of the samples were analyzed for measurement of COD_{Cr}, BOD_5, alkalinity, SS, VSS, Cl^-, TKN, and TP by the Standard Methods (APHA, 2005).

5.3 Results and Discussion

5.3.1 Water use and discharge of local households

Figure 5-8 describes water flow of 100 households in Lai Xa hamlet. Since the area is not covered by water supply network, underground water from a private drilled well was the main source (97.2%) providing water to the houses. The underground water is pumped from the well and then passes through a filter tank with sand, gravel, anthracite. The filtered water is stored in a tank and distributed through a plumbing system for washing, cleaning, bathing, toilet flush, *etc*. Besides underground water, rainwater was considered as another main source because it was used in 88.9% of households for drinking and cooking. Rainwater harvesting is a traditional way as people trust quality of this source. During rainy season, rainwater is collected by from house roof flowing into a gutter connected to a tank. The harvested rainwater is used for drinking and cooking in dry season. Public dug well and bottled water were also other water sources, however these sources were rarely used (1.4%). The public dug well water has been polluted but a small number of households nearby the well keep using the water after filtration.

Septic tanks are the popular facilities for treating waste from cistern-flush or pour-flush toilets. Since the sewerage systems are lacked in the area, greywater and septic tank effluent are discharged into a small pit in each household, and then to local drainage canal before flowing to agricultural field.

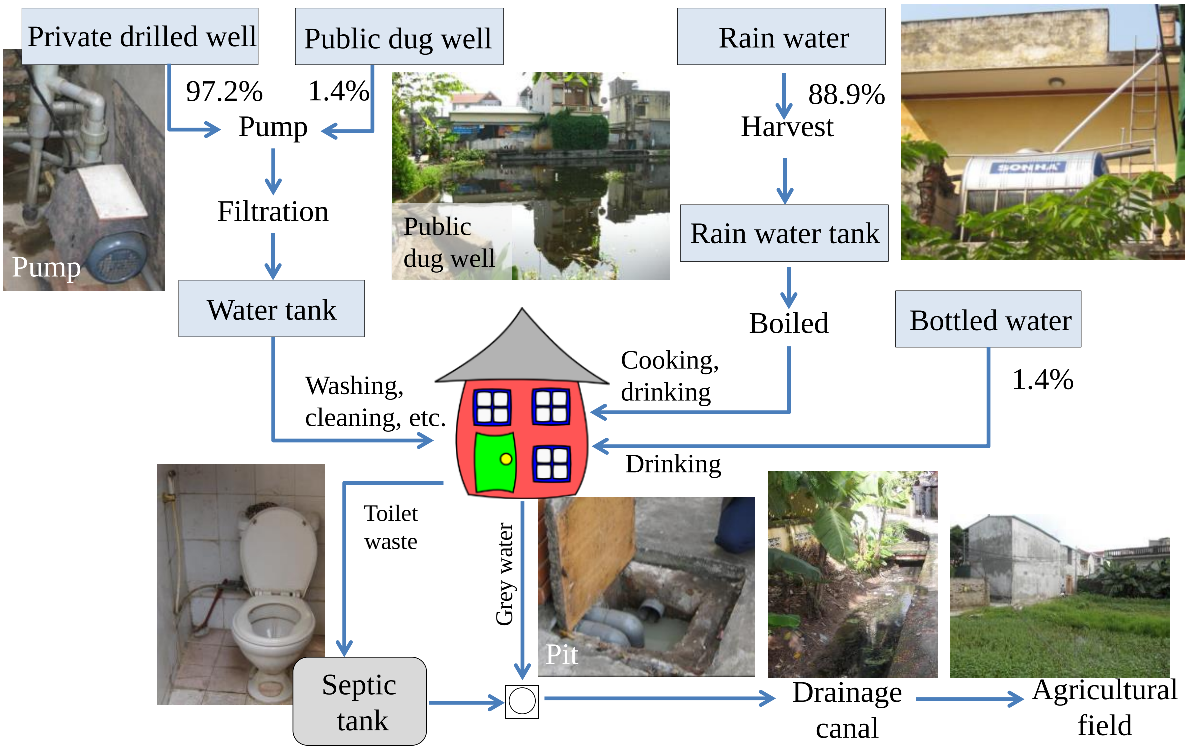


Figure 5-8 Schematic of water flow for 100 households in Lai Xa hamlet.

5.3.2 Septic tank characteristics

Characteristics of 46 septic tanks collected from structured interview are described in **Table 5-2** in which 21 tanks located inside the target watershed. The round septic tank comes from one household who utilized a previous biogas system.

It can be said that structure of septic tanks were not bad as it met the Vietnamese code in terms of size and number of chambers. Septic tanks were big (3.3 m^3) since almost people often consider big tank means good performance. This size is bigger than U.S. or European standards for a septic tank serving for a single house of five members (Nguyen, 2008). The septic tanks were constructed mostly based on practical experience. However, desludging condition of the septic tanks was at low level. All of the septic tanks have not desludged yet although they worked for 10.2±4.0 years. Due to long operation with no desludging, septage in the septic tanks were over-accumulated. The sludge accumulation shortens hydraulic retention time in a septic tank, one of influential factors affecting settling performance and anaerobic digestion. Performance of the septic tanks at Lai Xa hamlet, therefore, is expected to be limited.

Table 5-2 Characteristics of all septic tanks (n = 46)

Septic tank characteristic	Unit		Vietnamese code
Tank size			
Avg. ± S.D.	m^3	3.4±1.24	> 3
Median	m^3	3.24	
Three chamber septic tank	%	100	> 2
Tank shape			
Rectangular	%	97	
Round	%	3	
Number of user	People	5.0	
Non-desludging interval (Avg. ± S.D.)	year	10.2±4.0	

Note: Avg. and S.D. stand for average and standard deviation, respectively

Table 5-3 showed that septic tank effluents were polluted with high concentration of organic materials, nutrient contents, and suspended solids. The polluted effluent can be explained as anaerobic digestion did not effectively decompose organic matter. It can also be understood that settling process in the septic tanks was very limited and a large amount of solid matter was carried over in the effluent. The second chamber of the septic tanks is expected to contain an excessive sludge accumulation.

A huge variation in the effluent quality was obtained showing the difference in septic tanks' condition. Septic tank performance is dependent on wastewater characteristics, septic tank O&M such as user's habit or chemical use.

The ratio of VSS/COD_{Cr} = 0.33 indicating that organic materials were mostly in soluble phase. Because the wastewater from households including septic tank effluent is discharged directly to local drainage canal, it can be said that the receiving canal is polluted. SS and VSS were relatively low as compared to BOD_5 and COD_{Cr}, indicating significant amount of solid matter was removed though the tank. However, BOD_5 and COD_{Cr} were still higher than ordinary sewage influent of developed countries.

Table 5-3 Quality of septic tank effluent (*n* = 46)

Parameter	Unit	Min	Average	Max	Standard deviation	Median
pH	-	6.86	7.56	8.86	0.42	7.50
E.C.	mS/cm	0.96	2.28	5.40	0.42	2.20
Temperature	^{o}C	18.20	21.17	24.90	1.82	21.40
SS	mg/L	12	243	2,630	473	76
VSS	mg/L	12	200	2,030	377	69
BOD_5	mg/L	60	385	2,350	465	240
COD_{Cr}	mg/L	91	605	3,525	738	406
TKN	mg/L	1.3	55.32	691.6	119.1	13.6
TP	mg/L	0.9	13.5	145.5	24.7	5.4
Cl-	mg/L	9.0	171.4	625.0	161.6	131.5
Total Coliform	CFU/100mL	1.0×10^{7}	1.1×10^{7} 8.5×10^{5}*	3.5×10^{8}	5.1×10^{7}	9.0×10^{5}

Note: Value of geo-mean

5.3.3 Contribution of septic tank pollution load to water environment

Canal flow-rate and water quality patterns

Wastewater flow-rates at the outlet of the target watershed throughout 48 hours showed two distinct peaks, the daytime and the evening peak, and low discharge at late night (**Figure 5-9**). This pattern can be understood as the discharge from water-consumsing activities such as bathing, laundry, toilet flushing, kitchening, *etc*. by the residents in the watershed. Although the pattern showed two peaks similarly to water consumption pattern of urban residents mentioned in Chapter 3, the peaks lasted longer and quite equaled.

Average discharged amount was calculated as 23 m^3/day. The daytime peak (5 AM-3 PM) and evening peak (6 PM-11 PM) accounted for about 49% and 34% of total discharge throughout a day, respectively. Discharge amount per person was then estimated as 96 L/cap/day, which was similar to water consumption amount (92 L/cap/day) investigated in the same area by Busser *et al.* (2006).

Busser *et al.* (2006) also estimated toilets contributed 10-32% to total discharge amount in Lai Xa hamlet. In our survey, the households equipped with cistern-flush toilets (6 liter per flush). Toilet discharge was then calculated as about 7 m^3/day, accounting for 30.4% of total discharge amount.

Septic tank pollution load

Pollution loads from all septic tanks in the watershed were estimated based on **Eq. 5-2** by effluent quality of 46 surveyed septic tanks and toilet discharged amount (**Table 5-4**). Since the concentrations of septic tank effluent had a wide range and data on TKN and TP might contain analytical errors, calculation of pollution loads relied on median values of septic tank effluent for COD_{Cr}, BOD_5 and SS. The data were compared with pollution loads from household wastewater in Chapter 4. It showed that septic tank contributed 18.3%, 21.9% and 17.2% of COD_{Cr}, BOD_5, and SS loads from household wastewater. Although the loads from greywater were bigger than those from septic tanks, the septic tanks still have an important role to control pollution loads from the households.

Quality of canal water during two survey days was presented in **Figure 5-10**. It shows that concentration of all parameters tended to be higher in the evening than in the morning.

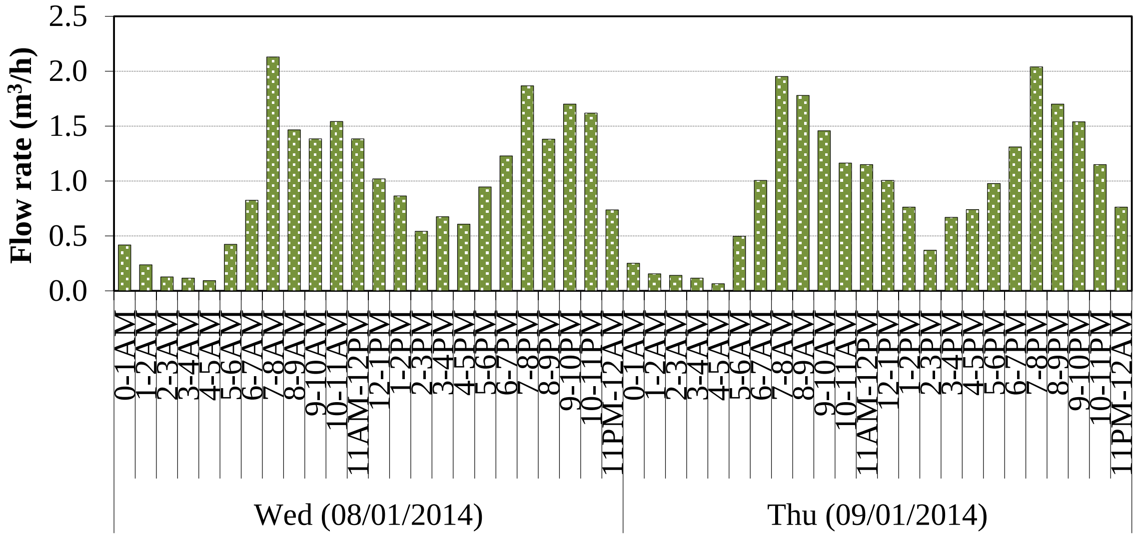


Figure 5-9 Wastewater flow-rates at the outlet of the target watershed throughout 48 hours (January, 8th – 9th, 2014)

Table 5-4 Calculated pollution loads from septic tanks and greywater

Pollution load (g/cap/day)	Septic tank effluent	Greywater	Household wastewater*
COD_{Cr}	12.0	53.6	65.6
BOD_5	7.0	24.9	31.9
SS	2.0	9.6	11.6

Note: * Data from Chapter 4 of the this thesis

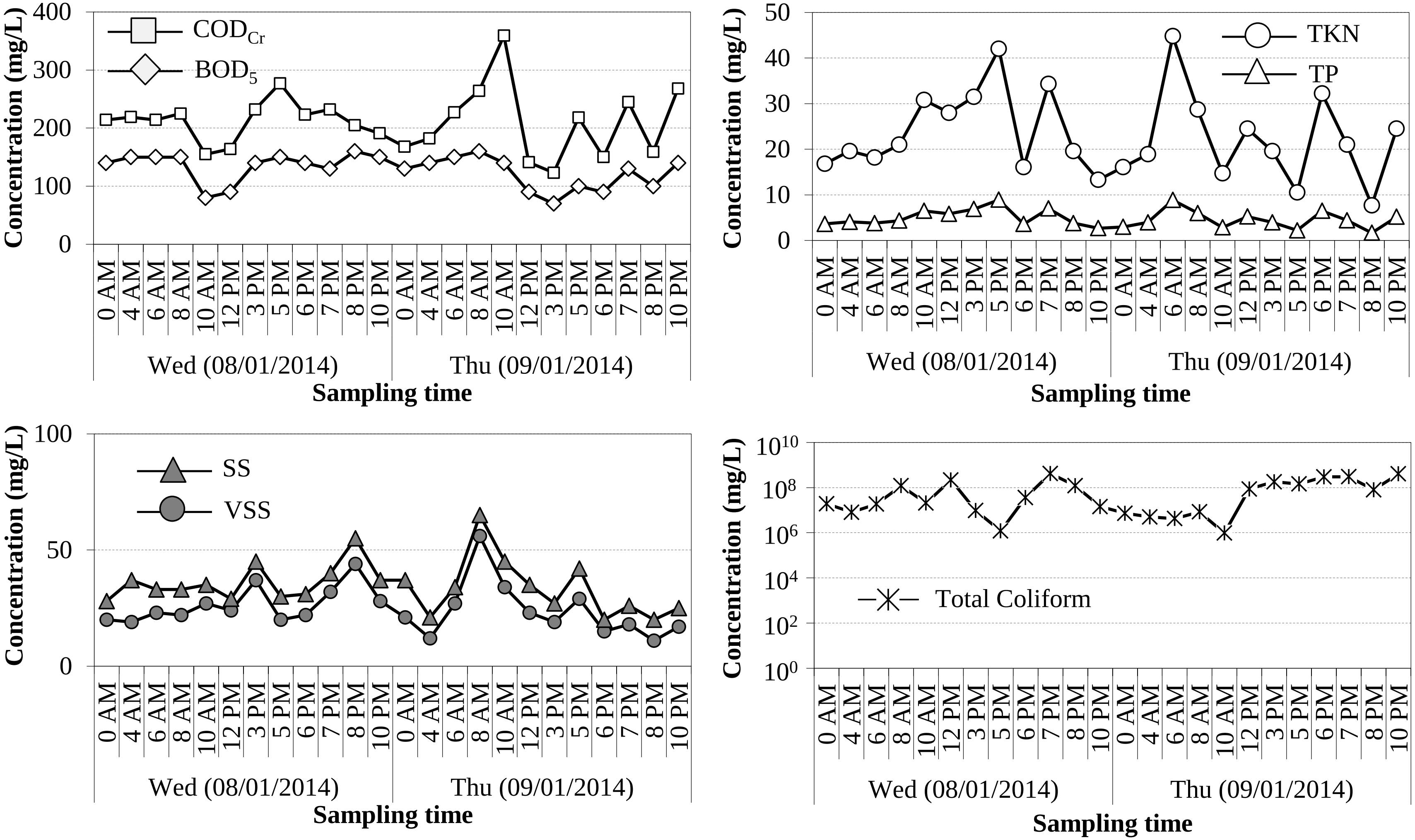


Figure 5-10 Quality of canal water at the outlet of the drainage watershed

5.3.4 Sludge accumulation and characteristics

Sludge accumulation rate

Septic tank structure and O&M differed among households resulting in a huge variation of septic tanks' performance. As a result, estimation of sludge accumulation rate was expected to be highly variable (**Table 5-5**). Although the septic tanks operated long time without desludging, we could not measure scum layer in all tanks. One possibility can be explained as desludging was conducted by breaking the floor which may break the scum layer on top of the septic tanks as well. In addition, desludging was conducted at the first chamber and sludge's depth was measured only at the point where the specific instruments were possible to access. The collected data; therefore, can represent sludge accumulation and characteristics at the first chamber at a particular point.

The average sludge accumulation rate was then calculated as 0.04 ± 0.05 L/cap/day, which was much lower than other referenced data. Temperature, input waste quality and discharge rate, etc. of Hanoi are different from other countries, anaerobic digestion is expected to be different as the result. Anaerobic digestion is more efficient in tropical zoned countries than in temperate zoned countries. Therefore, accumulated sludge volume in low-temperate zone is often higher than that in tropical zone (Brandes M., 1978). In addition, improper design of the septic tanks and over excessive sludge accumulation can carry over the sludge by over-flow, which can be seen from Table 5-3 that SS concentration of septic tank effluent was high. Another reason for the lower sludge accumulation rates observed in this study could be attributed to factors such as sampling method which was possible to measure at particular point in the septic tanks which may not represent exact level of sludge.

The USEPA (2002) suggested that the sludge and scum accumulation should not exceed 30% of septic tank volume. Assuming that area of the first chamber occupies two-third of a septic tank's area, the pumping frequency for removing sludge and scum accumulated was estimated using 30% average volume of the septage level (*i.e.*, sludge and liquid) in the tank and average number of user. The recommended pumping frequency for these septic tanks was calculated to be 7.7 ± 6.1 years once again indicating that solid accumulation were highly variable. The local septic tanks had long desludging intervals until desludging was provided in this survey (10.2±4.0 years). If desludging was not executed, the septic tanks are expected to have longer non-desludging intervals. Excessive sludge accumulation caused by long operating period reduces septic tank performance.

Most current septic tanks in Vietnam are constructed with big size to keep the tank operated longer. To reduce construction cost and make favorable management, a 2 m^3 septic tank is suitable for a five member household. In addition to appropriate design and operation, sludge pumping out should be conducted no later than 4 years to ensure septic tank's performance. However, it should be noted that this pumping frequency may be overestimated as scum accumulation was not included in the estimation.

Table 5-5 Comparison of sludge accumulation rates of this study with other studies

	Hanoi (This study)	Ontario, Canada [1)]	Ireland[2)]	France[3)]
Sample number (*n*)	*n* = 46	*n* = 29	*n* = 28	*n* = 33
Sluge accumulation (L/year)				
Average	60.6±76.0	79.9±40.7		
Minimum	6.9	20.3		
Maximum	393.9	161.7		
Median	33.2	80.6		
Sludge accumulation rate (L/cap/day)				
Average	0.04±0.05		0.234	0.20
Minimum	0.01			
Maximum	0.30			
Median	0.03			

[1)] Lossing *et al*. (2010) for 7 year-old septic tanks

[2)] Gray, N. (1995)

[3)] Phillip, H. *et al*. (1993) for 3 year-old septic tanks

Septage characteristics

Cylinder sampling had significantly lower values than composite sampling for same septic tanks (p=0.002 by paired t-test). Since it was likely to be difficult for the cylinder sampling to collect sludge at bottommost part of a tank, this study employed the composite sampling.

Composition of septage (*i.e.*, stored septage) is shown in **Table 5-6**. Neutral pH of septage (pH = 7.59) is a good condition for metabolic activity. Temperature is an important factor for anaerobic digestion. Optimum growth temperature for anaerobic organisms is suggested to be above 20^{o}C. Since the survey was conducted in winter season (December and January) in Hanoi, the measured temperature of septage was quite low 18.5^{o}C, which means that anaerobic conditions in will be slower than that in summer time where higher temperature was observed. The BOD_5 account for 65.5% of COD_{Cr}, which means that the septage accumulated easily-degradable matter and therefore can be undergone further biological treatment process (BOD_5/COD_{Cr} = 0.3–0.8) (Metcalf and Eddy, 2003). The VSS/COD_{Cr} (0.64) indicated that organic matter was mainly in solid form and settling function would play a crucial role for pollutant removal in septic tanks. This information can support selection of treatment technology, *e.g.*, separation of solid and liquid phase can be beneficial. Concentration of nutrients (TKN and TP) in the septage is quite low may be due to analytical error.

Table 5-7 presents composition of fresh septage samples. Comparing to stored septage characteristics, it was found that septage types affected composition. BOD_5 and COD_{Cr} in stored septage were lower than fresh septage. TP was higher in stored septage then fresh septage, explained by sedimentation/precipitation during stored duration.

Table 5-6 Composition of septage samples (*n*=46)

Parameter	Unit	Min	Average	Max	Standard deviation	Median
pH	-	6.87	7.59	8.40	0.38	7.56
E.C.	mS/cm	1.00	2.60	5.00	0.92	2.60
Temperature	^oC	16.3	18.83	24.90	1.48	18.55
SV30*	%	2	61	100	34	66
SS	mg/L	520	14,420	46,780	11,800	10,360
VSS	mg/L	503	13,070	45,650	11,430	8,600
BOD_5	mg/L	450	13,290	37,500	9,300	11,500
COD_{Cr}	mg/L	920	20,290	78,700	15,200	17,740
TKN	mg/L	60.2	297.6	1445.5	267.0	218.8
TP	mg/L	12.6	153.8	1,204	284.6	50.8
Cl-	mg/L	3.0	238.7	440.0	97.4	232.5
Alkalinity	$mgCaCO_3/L$	130	2,016	3,100	677	1,965
Total Coliform	CFU/100mL	2.0×10^5	5.3×10^7	5.8×10^8	1.0×10^8	1.0×10^7

Note: *SV30 is sludge volume settled in a graduated cylinder after 30 minutes

Table 5-7 Composition of fresh septage samples (*n*=8)

		SS (mg/L)	VSS (mg/L)	BOD_5 (mg/L)	COD_{Cr} (mg/L)	TKN (mg/L)	T-P (mg/L)
Fresh septage (*n*=8)	Ave.	17,000	13,900	22,400	29,700	393	82
	S.D.	9,300	7,100	6,300	7,200	184	39

5.4 Conclusions

The study investigated the contribution of pollution loads from septic tanks to open water area and accumulated sludge characteristics by a case study in sub-urban area of Hanoi. Because septic tank O&M are different among households, quality of septic tanks' effluent had a huge variation. It was calculated that discharge from septic tanks contributed about 18.3%, 21.9% and 17.2% of COD_{Cr}, BOD_5, and SS loads to those loads from household wastewater. Therefore, the septic tanks are important to control pollution loads from the household. The high concentration of suspended solids in septic tanks' effluent due to low performance decreased at the outlet of the watershed as the solids settled down during transporting in the drainage canal. It is suggested that pollution loads from septic tank, as well as that at the canal should be further monitored to quantify the loads reduced by desludging.

Sludge accumulation rate varied widely and the average value (0.04 ± 0.05 L/cap/day) was smaller than that in some other countries in temperate zone. This may be understood as temperature is an important factor for anaerobic digestion. Another the reason can be explained as the sampling method was able to measure sludge depth at a particular point in the tank. Even though, these data are useful for the better management of septic tank as it is a parameter for septic tank design and estimation of desludging frequency. However, it should be noted that desludging frequency may be overestimated as scum accumulation could not be included in this survey.

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Publication

Original paper

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Chapter 6 Effects of septic tank management on septage composition

6.1 Introduction

According to the WHO/UNICEF 2010 Joint Monitoring Program, urban access to improved sanitation has risen to 57 and 79 percent in South Asia and Southeast Asia, respectively (WHO/UNICEF, 2010). That was 94 percent in Vietnam, comparing to 61 percent in 1990 thanks to the investments in the provision of improved toilets. However, the management of septic tanks, particularly the management of the sludge stored in septic systems (*i.e.*, septage) is one of the least addressed issues of urban sanitation and wastewater management (AECOM/SANDEC, 2010).

Septic tanks in Vietnam are inadequately designed and constructed, and they are only desludged when blockages appear or odor becomes unbearable (V. T. Yen-Phi *et al.*, 2010). The septic tanks, therefore, do not perform well as a treatment system since they tend to be too full and rarely desludged. High concentrated septage caused by non-regular desludged septic tanks was stated by the World Bank as the major contribution of waste load that impaired the water environment such as the Dong Nai river basin and the Nhue-Day river basin (World Bank, 2006). It should not be disregarded that a reform of septic tank management and a proper treatment of septage are necessary to better the current situation.

Knowledge of septage characteristics is essential in determining the proper alternatives of septage handling and disposal. Reference information reported the characteristics of septage. However, the results showed the huge variety of septage composition which is likely due to the different management of the corresponding septic tank. The septage composition varies considerably depending on tank’s feature and desludging manner, such as septic tank size and design, number of people using the toilets and their habits of use, desludging interval, hygiene manner and climatic conditions. Comprehensive understanding of the quality of septage considering the effects of relevant factors may contribute to the improvement of septic tank management in Vietnam.

The objectives of this chapter are to investigate the management of household septic tank and the composition of corresponding septage, and to evaluate the effects of septic tank management on septage composition, based on a case study in Danang, Vietnam.

6.2 Materials and Methods

6.2.1 Study site

Danang, one of the five centrally-governed cities in Vietnam, is the largest port city in the central region. The city has six urban districts and two suburban districts occupied by 926,000 people (GSO, 2010). Recently, Danang has become a center of economy, culture and education, which has been experiencing rapid growth and urbanization. Together with impressive city expansion, Danang is facing environmental issues. About 80% of the households living in Danang are served by septic system, but only 16% of these septic tanks are directly discharged into sewer pipes (Tran, 2010). Effluent of the remains is soaked into underground.

At present, Danang Urban Environmental Company, (*i.e.*, Danang URENCO) is a major organization taking responsibility for septage collection, providing the desludging service through individual vacuum trucks. Collected septage is transported and treated at the sludge treatment plant in Khanh Son landfill site. **Figure 6-1** presents quantity of waste the landfill received from 2007 to 2011. During the five years, total waste input as well as septage amount to the landfill increased, and the proportion of septage to total waste input to the landfill was about 4.5%. In 2004, the World Bank has assisted Danang in building a septage treatment plant and introducing regularly desludging programs. This project aimed to empty 20,000 septic tanks a year with a five-year rotating cycle. Unfortunately, it funded only 33,000 tanks instead of the proposed 100,000 during 2004 to 2008 as the project was not integrated into local policies (AECOM/SANDEC, 2010).

The treatment system of septage at the landfill was described in **Figure 6-2**. Septage is transported to the landfill by vacuum trucks, and then is discharged to receiving tank. After that, the septage flows into six gravitational settling tanks where it is separated into sludge and wastewater. The wastewater is pumped to be treated together with the leachate of the landfill while the sludge is dried and buried in the landfill with domestic waste.

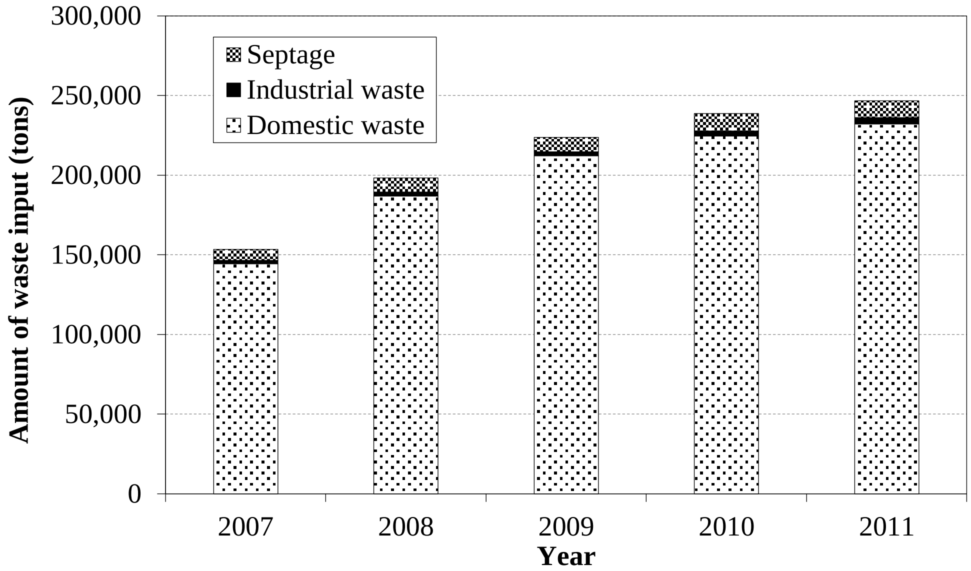

Figure 6-1 Quantity of waste input to Khanh Son landfill site (Local report, 2012)

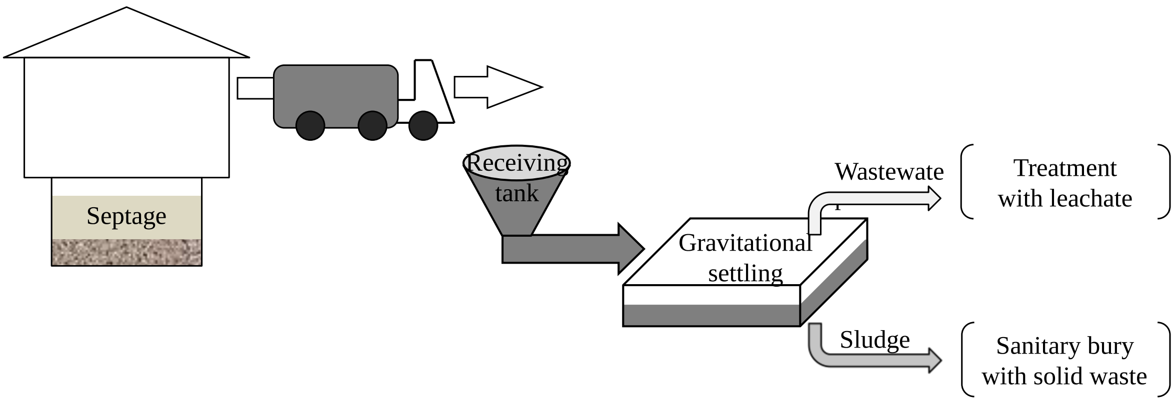

Figure 6-2 Septage collection and treatment at Khanh Son landfill site

6.2.2 Interview

A sampling program started by a call from households that require desludging service. An interview was conducted at the households with a structured interview. **Figure 6-3** shows the households for sampling. The interviews included information on septic tanks (*e.g.*, type of sanitation facilities, volume of flushing water, user habits), septic tank characteristics (*e.g.*, water-tight tank, tank shape, number of chambers), discharging location of effluent, and desludging frequency (**Table 6-1**). The respondents were the households, who had contacted URENCO for desludging purpose during 9 to 24 March 2012. Thirty-six households had contacted URENCO but only 20 respondents could provide the above information.

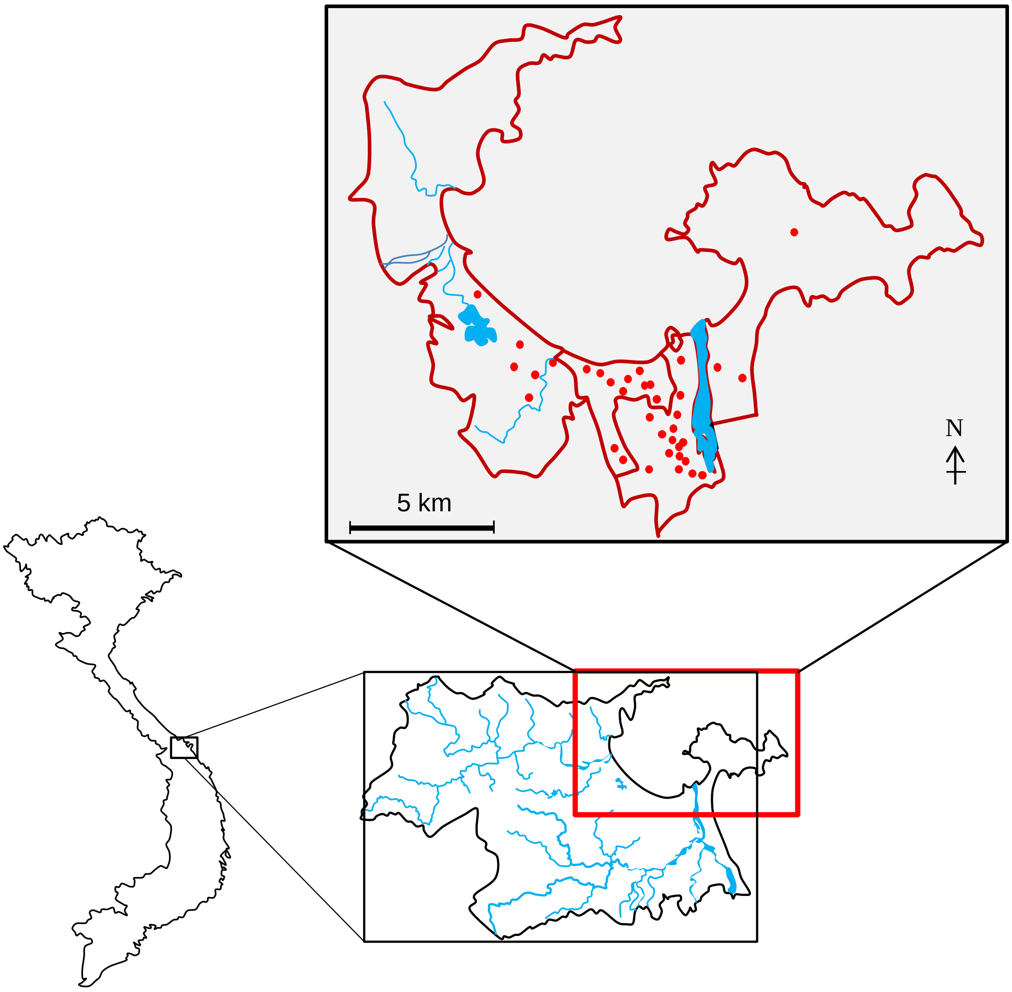

Figure 6-3 Map of Danang and sampling points. All of sampling points are located in urban areas of the city.

Table 6-1 Contents of structured inteview for households in Danang, Vietnam

Item	Content
Toilet facility	
	Cistern-flush, pour-flush
	Flushing volume
Septic tank structure	
Shape	Rectangular, cylindrical
Material	Brick, concrete
Number of chamber	One, two, three, *etc.*
Desludging condition	How many times of previous desludging
	Latest desludging
Septic tank connection	Underground, open water area, drainage system
Chemical use	Enhancement of performance

6.2.3 Septage sampling and analysis

A vacuum truck collects septage from each household and then disposes of it at the Khanh Son sludge treatment plant. Two septage samples were collected for each septic tank: one was obtained at the septic tank when it had been accessed (*i.e.*, on-site septage sample) and the other was executed as composite sample at the sludge treatment plant while septage was being discharged from the vacuum truck, hereinafter referred to as on-site septage sample and discharged septage sample, respectively.

We measured the concentrations of Cl^- for on-site and discharged septage samples. The measurement of pH, SS, VSS, TDS, COD_{Mn}, COD_{Cr}, BOD_5, TKN, NH_4-N, T-P, PO_4-P, and alkalinity were conducted only for each discharged sample. All of these measurements were carried out in the laboratory of Environment Protection Research Center (EPRC) of Danang University of Technology (DUT) by the Standard Methods (APHA, 2005).

6.2.4 Data analysis

Adjustment of sample concentrations with Cl^- concentration

To eliminate the effect of dilution caused by cleansed and/or rinsed water added to the septic tank by workers during desludging work, a dilution factor can be obtained by a comparison between the Cl^- concentrations of on-site and discharged septage samples.

In addition, the concentration of each discharged septage sample should be adjusted to allow the elimination of diluted water by flushing toilets, applying the method proposed by Harada *et al*. (2008). In this assumption, each person produces the same Cl^- concentration of excreta and Cl^- concentrations vary together with the dilution by flush water. The adjusted concentration can be calculated using Cl^- concentration as follows:

$$\boldsymbol{C'_{i,j} = C_{i,j} \times \frac{Cl_{Max}}{Cl_j}} \quad \textbf{(Eq. 6-1)}$$

in which $C'_{,i,j}$ is the adjusted concentration of item i (*e.g.* BOD_5, COD_{Cr}, SS) of the sample from septic tank j (mg/L), $C_{i,j}$ is the observed concentration of item i (*e.g.* BOD_5, COD_{Cr}, SS) of the sample from septic tank j (mg/L), Cl_{Max} is the highest concentration of Cl^- among all samples (mg/L), and Cl_j is the concentration of Cl^- of the sample from septic tank j (mg/L).

Analysis of the effect of septic tank management on septage composition

Types of toilet facilities, household sizes, septic tank volumes and desludging intervals obtained from the structured interview are considered as factors of septic tank management that influence the septage composition. To examine the effect of desludging condition on septage composition, the following equation was introduced to indicate the specific desludging interval of a septic tank (Harada *et al*., 2008):

$$\boldsymbol{P_{SI} = \frac{P_I \times S}{V}} \quad \textbf{(Eq. 6-2)}$$

in which P_{SI} is the specific desludging interval of septic tank (month·person/m^3), P_I is the desludging interval of septic tank (month), S is the household size that was using a septic tank (person), and V is the volume of septic tank (m^3).

The impact of desludging condition on septage composition was investigated by a correlation analysis.

6.3 Results and Discussion

6.3.1 Septic tank management

Differently from the situation in urban areas of Hanoi, human excreta of the surveyed households in urban Danang were discharged into cistern-flush toilets (50%) and pour-flush toilets (50%) and these toilets were connected to septic tanks (**Figure 6-4**). The septic tanks were rectangular or cylindrical shapes, but the former was more dominant (88.9% of septic tanks were in rectangular shape). All septic tanks connected to cistern-flush toilets whether they were rectangular or cylindrical had three compartments and mostly soak into underground. There was 18.8% of rectangular septic tanks connected to pour-flush toilets had two compartments. Only few numbers of all septic tanks were connected to sewer pipes, the remainings were soaked into underground. While the septic tanks in Hanoi are discharged into open water areas, the septic tanks in Danang are mainly penetrated into underground. Canter and Knox (1985) mentioned the potential for polluting ground water of septic tanks if septic tanks' effluents are percolated through soil. This is because of the migration of pollutants through soil and ground water systems. Therefore, performance of septic tanks might greatly influence the quality of urban environmental sanitation in urban Danang.

Desludging interval and accessing port to septic tanks are shown in **Figure 6-5**. Although desludging interval depends on the tanks' conditions, a desludging at least every two to five years is recognized as one of important factors on septic tank performance. In the case of Danang, septage were stored for more than five years for 85% septic tanks, and nearly 60% of the tanks were not desludged in the past (data not shown). It was found that the desludging interval had an average and a median of 9.5

years and 8.5 years, respectively. Our survey also found that 80.6% of septic tanks did not have any port to access. When desludging was executed, suction pipes were put into the tank *via* a hole drilled by vacuum truck's drivers. Not always the septic tanks were located under toilet's floor but outsides toilet room. During the survey, we found some septic tanks were constructed under bedrooms. With this situation, desludging is an uncomfortable work for the households and is not regularly conducted as the results. Indeed, more than half of desludging times were conducted due to septic tanks' blockage and/or offensive odor, and 39% was because of re-construction or repairment of the house (**Table 6-2**). Only 2% of desludging times was executed because the households think the septic tank have enough operation time to pump out septage. It can be concluded that most of septic tanks in urban Danang were not managed in proper manner and the performance were expected to be at quite low level. This situation is common in Vietnam as people do not have awareness about regular desludging.

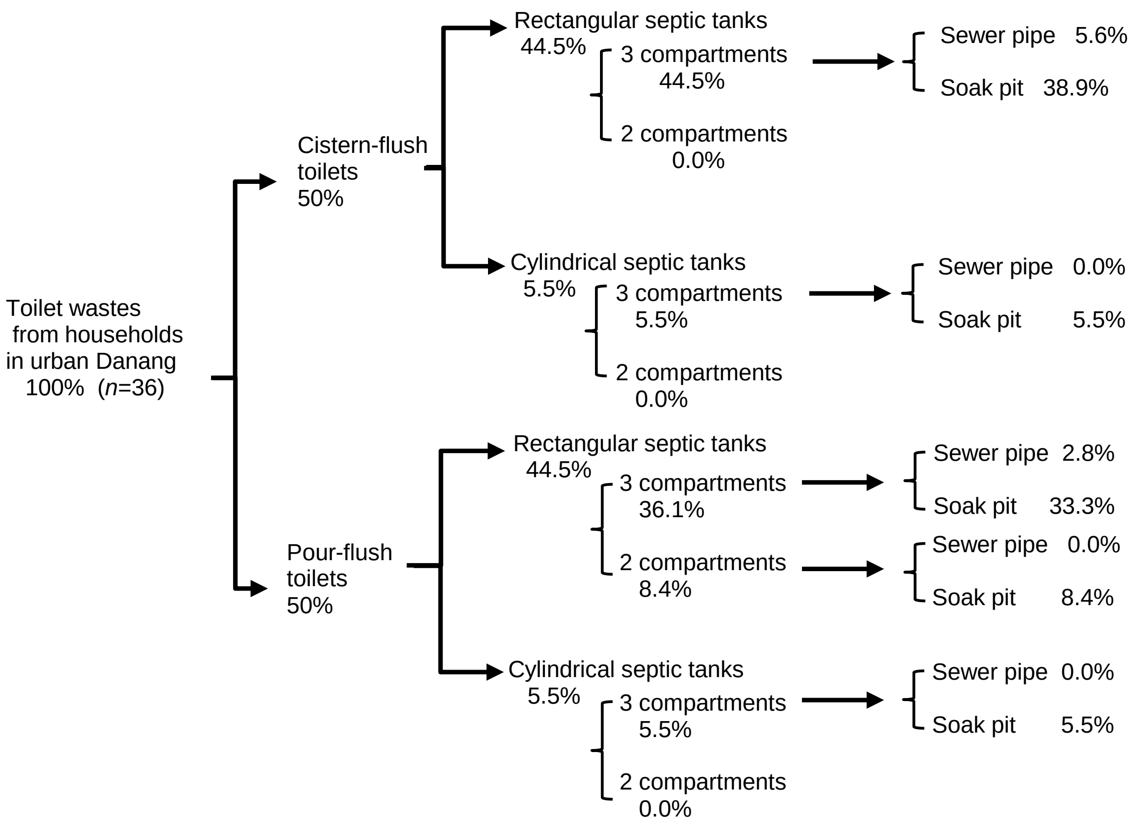

Figure 6-4 Toilet types and septic tank shaped of questioned households in Danang

Table 6-2 Reason for desludging of 36 septic tanks

Reasons for desludging	Proportion
Blockage and/or bad odor	52 %
House reconstruction or repair	39%
Free desludging by previous project	7%
Septic tanks operated long enough	2%

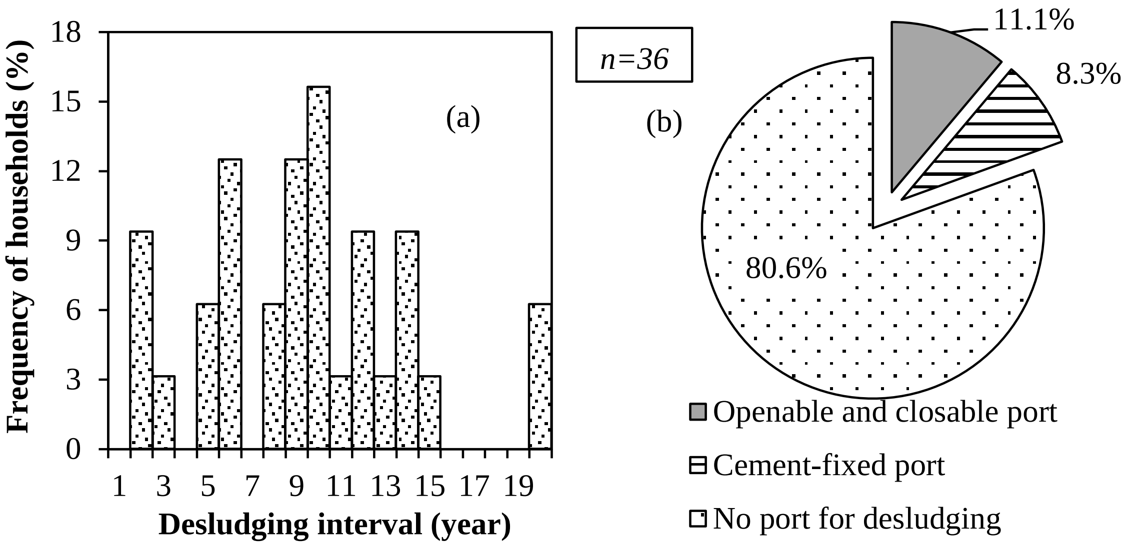

Figure 6-5 Conditions of septic tanks: (a) desludging intervals; (b) access to septic tanks

6.3.2 Septage composition

Table 6-3 presents the composition of septage derived from 20 septic tanks connected to cistern-flush and pour-flush toilets. The data had a wide variation because the septage composition depends on input waste quantity and quality, septic tank O&M. Actually, the septage composition always varies in every location due to the various septic tank performance, desludging work as well as analytical technique.

The results showed that concentration levels of septage derived from the septic tanks connected to pour-flush toilets were significantly higher than that connected to cistern-flush toilets (p=0.017; α=0.05). This difference might be explained by the variation in volume of flushing water and the longer average specific desludging interval (185 month•person/m^3 versus 106 month•person/m^3). The average pH of the former was 7.8 while that of the latter was 7.7 which are favorable when biological treatment of septage is considered. The septage for cistern-flush toilets and pour-flush toilets were well buffered, showing the alkalinity values were 2,163 mg/L and 2,208 mg/L, respectively. The BOD_5 of samples in the septic tanks connected to cistern-flush toilets and pour-flush toilets represented 30% and 33% of the COD_{Cr}, respectively, indicating that the septage was stabilized to some degree but could be still biodegradable (MetCalf & Eddy, 2003). The ratios of VSS/COD_{Cr} were 0.72 and 0.76 for septage in cistern-flush toilet septic tanks and pour-flush toilet septic tanks, respectively. These high values indicate that organic matter was mostly in particulate phase.

Although average non-desluding intervas of septic tanks in Danang (9.5 years) were not much different from that in Hanoi (10.2 years), septage composition was different. The septage in Hanoi contained higher easily-biodegradable organic contents while the septage in Danang contained quite stabilized organic matter. However, organic matter in both septage was found mainly in solid form. Comparing with the septage in Danang, septage in Danang contained higher nutrient contents (TKN and TP). The different data confirm that selection of septage treatment technology should be based on local septage characteristics.

The septage composition investigated by the U.S. Environmental Protection Agency had a wide range (US EPA, 1994), and the results found in this survey lied in this range, except the parameters related to nitrogen contents. Although the concentrations of ammonia and total nitrogen of the septage in this survey were higher than those mentioned by the US EPA, these results were consistent with the values found in Bangkok septage reference (Koottatep *et al*., 2001). One of the possible reasons of this trend could be understood that septic tanks in Danang and Bangkok mainly receive black water only, whereas septic tanks in the US received both of grey and black water. It can be said that much nutrients of septage in Danang might be become an incentive to achieve environmentally-friendly management of septage in which the nutrients are recovered for crop fields.

Table 6-3 Composition of septage derived from septic tanks connected to cistern-flush toilets (*n*=10) and pour-flush toilets (*n*=10) in comparison with other locations

	pH	Alkalinity (mg/L)	SS (mg/L)	VSS (mg/L)	TDS (mg/L)	COD_{Cr} (mg/L)	BOD_5 (mg/L)	NH_4-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	T-P (mg/L)
Cistern-flush toilets (*n*=10)											
Avg.	7.7	2,163	27,691	22,705	5,515	31,470	9,225	312	2,102	119	927
S.D.	0.3	380	25,929	21,270	1,987	24,081	7,343	220	1,676	54	781
Pour-flush toilets (*n*=10)											
Avg.	7.8	2,208	45,170	37,130	7,076	48,990	16,133	456	3,390	147	1,178
S.D.	0.3	551	18,752	17,606	1,292	12,808	7,051	143	1,178	19	450
US EPA (1994)											
Min	1.5	522	-	95	-	1,500	440	3	66	-	20
Max	12.6	4,190	-	51,500	-	703,000	78,600	116	1,060	-	760
Avg.	-	970	-	9,027	-	31,900	6,480	97	588	-	210
Bangkok (T. Koottatep *et al*., 2001)											
Min	6.7	-	1,000	-	-	1,200	600	120	300	-	-
Max	7.8	-	44,000	-	-	76,000	5,500	1,200	5,000	-	-
Avg.	7.5	-	15,000	-	-	17,000	2,800	350	1,000	-	-

6.3.3 Effects of desludging condition on septage composition

Adjusted concentrations of COD_{Cr}, BOD_5 and SS of the septage are described against the specific desludging interval. It was found for septic tanks connected to pour-flush toilets that the adjusted concentration of COD_{Cr}, BOD_5, and SS of sludge stored in the septic tanks increased by the specific desludging interval, although no clear relation for that connected to cistern-flush toilets. Regarding septage for pour-flush toilets, coefficients of determinant (R^2) examined between the specific desludging interval and adjusted concentration of COD_{Cr}, BOD_5, and SS were high, presenting 0.68, 0.57 and 0.72, respectively (**Figure 6-6**). This relationship could be explained by more accumulation of solid matter of septage stored for longer desludging interval.

Correlation equations between the specific desludging interval and the adjusted concentrations of COD_{Cr}, BOD_5 and SS were described as follows:

$$COD_{Cl} = 0.54 \times P_{SR} - 14.22 \qquad (R^2 = 0.68) \; (1)$$

$$BOD_{5,Cl} = 0.18 \times P_{SR} - 4.79 \qquad (R^2 = 0.57) \; (2)$$

$$SS_{Cl} = 0.68 \times P_{SR} - 45.49 \qquad (R^2 = 0.72) \; (3)$$

If the household size and the septic tank volume are fixed, a longer desludging interval could provide a higher concentration of septage. This trend can be mainly understood as a mixture of a decomposition process of organic matter by anaerobic digestion and an accumulation process of solid matters by settling functions. As the results, concentration of pollutants in septage increased with an increase in the specific desludging interval.

Higher septage concentration due to longer desludging interval should be given attention for septage treatment design. For future direction of septic tank and septage management, septage treatment needs to be designed based on desludging strategy.

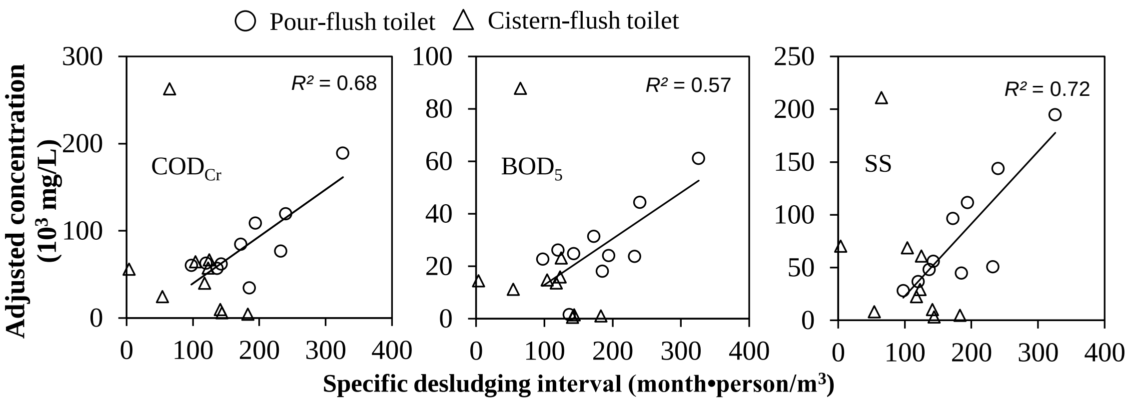

Figure 6-6 Adjusted concentrations of COD_{Cr}, BOD_5, SS of septage from the septic tanks connected to pour-flush toilets and cistern-flush toilets depending on the specific desludging intervals.

6.4 Conclusion

The septic tanks are the major facilities to treat toilet waste generated from households in Danang but were observed on poor operation and management conditions. The septic tanks had 9.5 years of non-desludging. This resulted in highly concentrated concentrations and stabilized organic matter (BOD_5/COD_{Cr} was about 30%). The septage could still undergo further biological treatment and the nutrients-rich septage may be attractive for agricultural use after proper treatment. It was also stated that pollution loads from the septic tanks connected to pour-flush toilets could increase and septage became more high-concentrated when increasing the specific desludging interval but no clear relation for that connected to cistern-flush toilets (R^2 for COD_{Cr}, BOD_5, and SS were 0.68, 0.57 and 0.72; respectively).

As the septage composition data have a high variation and localized, selection of treatment technology must be addressed to this issue. In addition, septage composition is much affected by desludging interval, design of treatment technology should be considered after desludging strategy is developed.

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Presentation

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Chapter 7 Social acceptance of septage-oriented compost

7.1 Introduction

Septage is highly variable and organic and has offensive odor. The septage may also become a host for disease-causing viruses, bacteria, and parasite. (USEPA, 1999). The World Bank stated highly concentrated septage caused by non-regular desludged septic tanks was the major contribution of waste load that impaired the water environment such as the Dong Nai river basin and the Nhue-Day river basin (WB, 2006). Therefore, septage has to be properly treated.

Three-fourth of Vietnamese population is involved in agricultural activities. Therefore, treatment of septage as compost can provide good soil supplement for cropping. Due to economic development, chemical fertilizer becomes a more preferable source of nutrients. However sludge compost was found to provide effective sources of N, P and K for crop production (Warman and Termeer, 2005). There should be a move back to use compost as a soil amendment.

Septage contains high concentration of pathogens, helminthes and needs to be appropriately treated (Yen-Phi *et al*., 2010). Biological activity during composting process generates heat, resulting in a rise of temperatures that are sufficiently high to destroy pathogens (USEPA, 1999). However, septage hygiene is still a growing concern to food consumers who buy vegetables that is fed by septage-oriented compost.

The chapter aims at evaluate public awareness of septic tank and septage management and their acceptance of compost made from septage based on the data obtained from structured interviews in urban Hanoi (*n*=100), sub-urban Hanoi (*n*=100) and urban Danang (*n*=36) conducted throughout the research.

7.2 Materials and Methods

7.2.1 Structured interviews to households

This whole research (Chapter 3, chapter 5 and chapter 6) included structured interviews in urban (n=100) and sub-urban (n= 00) areas of Hanoi, and urban areas (n=36) of Danang, Vietnam. Questions about septic tank and septage management, and the acceptance of compost made from septage were given to all interviewees throughout the surveys. Detailed contents of the questions are listed as follows (**Table 7-1**).

The interviews conducted to households included the households desludged their septic tanks in sub-urban Hanoi and urban Danang. The number of questioned households is illustrated in **Figure 7-1**.

Table 7-1 Contents of structured interview for septic tank and septage management, and acceptance of compost made from septage

Item	Content
Septic tank management	- Understanding of role of frequent desludging?
	- Willing to comply if frequent desludging is obliged?
Septage management	- To where the septage is disposed after septic tank is desludged?
	- Are you agree to compost made from septage?

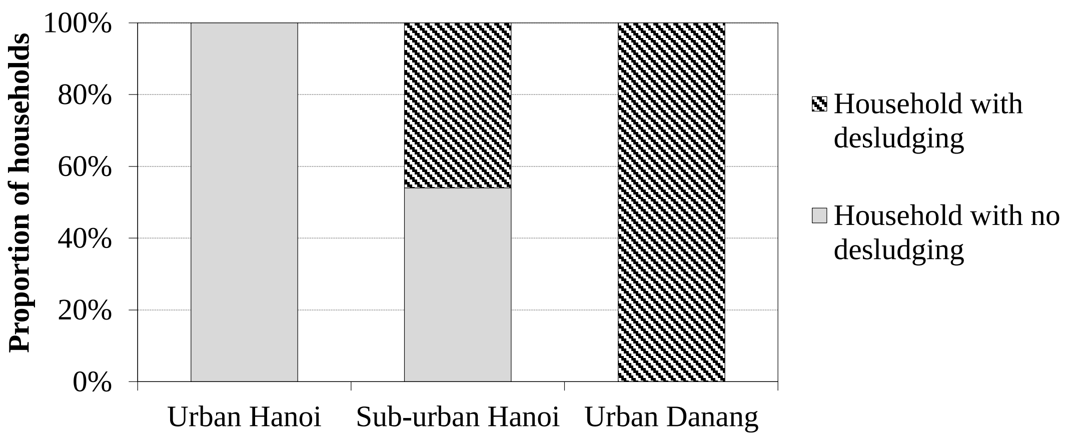

Figure 7-1 Number of questioned households throughout the whole research.

7.2.2 Observations

Collected septage is often illegally dumped by vacuum truck drivers. Therefore, it is difficult to conduct a structured interview for the driver. Instead, short interviews were implemented for several drivers while they were doing desludging works. Moreover, behaviors of truck drivers were also observed with taking note and photographing.

7.3 Results and discussion

7.3.1 Public awareness of septic tank management

Almost interviewees answered that they do not understand the role of frequent desludging. This can be easily understood from long non-desludging intervals investigated in Hanoi and Danang. Our surveys also found that almost all of septic tanks in Hanoi and a large part of septic tanks in Danang have no port to access. In addition, many of the households do not know exactly the place of septic tanks within their houses and where to access the tanks if desludging is needed. Particularly, septic tanks are sometimes located under bed-room floor, not under toilet floor as usual. These situations; therefore, can be the obstacles to frequent desludging. Due to the lack of knowledge, households often construct a big septic tank to maintain long operation. The average sizes of septic tanks are big (approx. 3.5 m^3) and even bigger than the U.S. standard for a household where septic tanks receive both greywater and toilet discharge.

7.3.2 Public awareness of septage management

Throughout the structured interviews at three study site: urban Hanoi, sub-urban Hanoi, and urban Danang, most of households did not know where collected septage is disposed to (**Figure 7-2**). There were 88%, 90% and 72% of the interviewees did not know the place for septage disposal. They only concerned that the septage is pumped out of their septic tanks. Residents in Danang seemed to know more clearly about disposal location of septage. In the year 2004, the WB funded a free desludging in Danang and this project may help local residents know more about septage management.

By observation of desludging service in Hanoi and Danang, it showed that desludging works in the cities are mainly conducted by vacuum trucks from private companies. In highly populated areas, it is difficult for the trucks to access septic tanks. It can be said that desludging is not convenient for the households.

Moreover, once the septage is collected, it is often disposed at the nearest possible place, especially in Hanoi. The possible place, according to drivers, can be any receiver such as water bodies. The septage can also be used for agriculture but it is not treated properly. This may causes potential health risk as the septage contains helminthes, pathogens, *etc*.

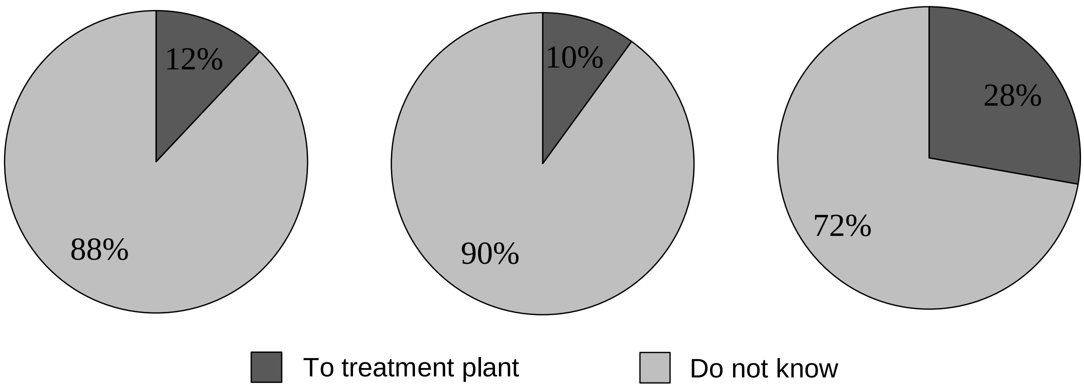

Figure 7-2 Understanding to which collected septage is transported of total questioned households: Urban Hanoi (*n* = 100); Sub-urban Hanoi (*n* = 100); Danang (*n* = 36).

7.3.3 Public acceptance of compost made from septage

Figure 7-3 displays public opinion towards compost made from septage. Although a large number of the respondents accepted septage-oriented compost (more than 80% in all study sites), there were some respondents did not agree (less than 10%). Few number of the respondents indicated that they did not know whether septage-oriented compost is acceptable.

A small number of respondents in Hanoi (5% in urban and 3% in sub-urban areas) said that they only accept compost made from hygienically treated septage. They were worried about pathogens in the compost made from septage. This statement was not found for the respondents in Danang

Interestingly, sub-urban residents tended to show less worried than urban residents about this matter. It can be understood that those are closed to agriculture think that there are no problem to use compost made from septage whereas urban residents disclosed the concern about hygienic condition of compost product.

Only hygienic quality of compost products attracts concern of the public. Heavy metals, which should also be considered are not a concern of the public.

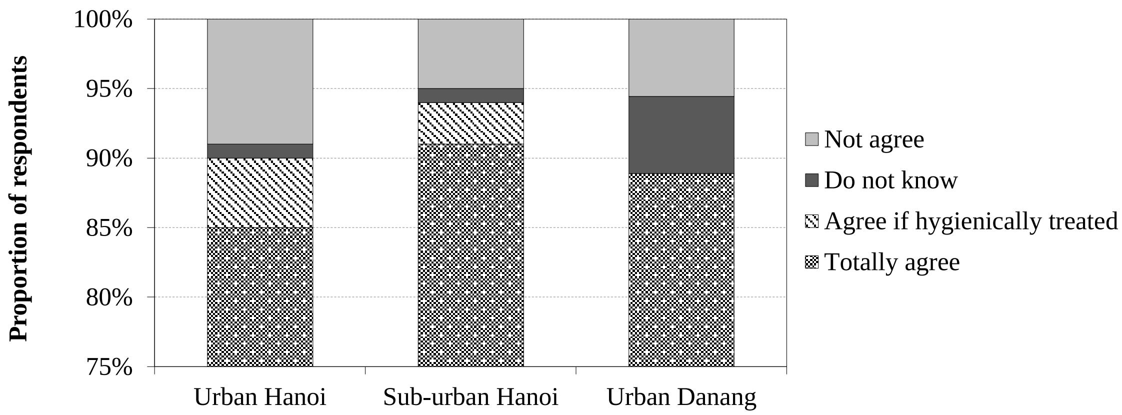

Figure 7-3 Public opinions to septage-oriented compost: Urban Hanoi (*n* = 100); Sub-urban Hanoi (*n* = 100); Danang (*n* = 36).

7.4 Conclusions

Considering composting as a suitable option for septage treatment, study on social acceptance of septage-oriented compost was conducted. Although a large number of interviewed households (more than 80%) accepted septage-oriented compost, a small number of them concerned about hygiene of compost products. They were worried about pathogens in the compost made from septage. Some households said if compost made from hygienically treated septage, they are willing to accept. Composing is an acceptable option but health safety in terms of pathogens, heavy metals should be considered.

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Chapter 8 Conclusions and recommendations

8.1 Conclusions

Developing countries lack of sewerage systems causing a large amount of wastewater from households is discharged into open water areas. The situation becomes seriously as septic tanks, the most on-site toilet waste treatment, are not properly managed. As long as sewerage systems have not been completely developed, the proper management of septic tanks is essential to enhance the tanks' performance and reduce pollution loads to water environment. In this context, this study is aimed at characterizing wastewater at household level, and then evaluating septic tanks' function based on case studies in urban areas of Vietnam. Some main results of this research is illustrated in **Figure 8-1**.

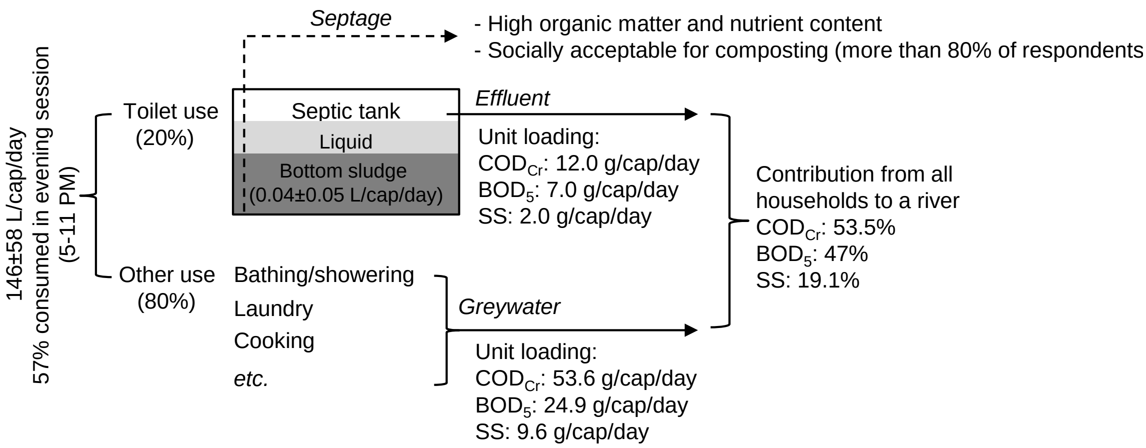

Figure 8-1 Illustration of some main results of the research

Water consumption and discharge of urban residents were characterized in urban areas of Hanoi. The results showed that average daily-per-capita consumption amount had a wide range (146±58 L/cap/day) because of various residential lifestyles. Per-capita water consumption amount of the households with the elderly was significantly lower than that of the households without the elderly ($p < 0.001$) as traditional water saving manners such as pour-bathing, laundry by hands, *etc.* were observed in the with-elderly households. Toilet flush happened throughout a day and contributed about 20% to total water consumption. Water consumption was a daily routine and each household had their own consumption patterns varying hourly. The highest water consumption was recorded in the evening (57% of daily consumption).

Wastewater concentration was affected by water consumption. Wastewater concentration patterns varied within a day and peaked at 3-4 PM. Because toilet use was the major water-consuming contributor at this time period, septic tank effluent released by toilet flush was not diluted, and then remained highly concentrated.

Discharge of household wastewater contributed about 22% to To Lich river in Hanoi. Average concentrations of COD_{Cr}, BOD_5, TKN, and T-P of household wastewater were 471 mg/L, 225 mg/L, 57 mg/L and 8 mg/L, respectively. A large part of organic matter and TKN of household wastewater were in soluble phase, while that of TP was in particulate phase. Pollution loads from household wastewater was estimated to contribute 53.5% to COD_{Cr} and 47.0% to BOD_5 loads at the river. TKN and TP contributed about 24.5% and 40% to the loads accumulated at the river, respectively. By comparing household wastewater and river water quality, it showed that the septic tanks were able to trap particulate matter to some degree but a significant amount of particulate matter was still released in to the river.

Pollution loads from septic tanks were estimated based on a case study in Lai Xa hamlet, Kim Chung commune, Hoai Duc district, a sub-urban area of Hanoi. The results showed that a large part of solids discharged from the septic tanks settles down during its transportation in the drainage. The septic tanks contributed 18.3% of COD_{Cr}, 21.9% of BOD_5 and 17.2% of SS loads from household wastewater. Sludge accumulation rate was estimated as 0.04±0.05 L/cap/day, showing a huge variation due to different septic tanks' conditions. The data can be used for a proper design of septic tanks and desluging frequency.

The effects of septic tank management on septage composition were investigated in urban areas of Danang. Urban residents in the city use cistern-flush toilets and pour-flush toilets, and then the flushed excreta go to septic tanks soaked into underground. The septage was stabilized to some degree but could still be further biodegraded. High nutrient contents in the septage might become an incentive to achieve environmentally-friendly treatment by hygienic recovering for crop fields. Correlations between specific desludging intervals (month•person/m^3) and the Cl^- adjusted concentrations of COD_{Cr}, BOD_5, and SS indicated that when the specific desludging intervals increased, an increase in the concentrations of COD_{Cr} (R^2=0.68), BOD_5 (R^2=0.57), and SS (R^2=0.72) were also found. If household size and septic tank volume are fixed, a longer operating period could provide higher septage concentrations due to excessive solid accumulation. From this point, it is clear that desludging frequency has a strong effect on septage composition.

When desludging is frequently conducted, collected septage must be treated properly to protect environmental sanitation. Although selection of septage treatment technology is based on septage composition, compost can be a good way to recycle nutrients as more than 70% of Vietnamese population is dependent on agriculture. Considering composting as a suitable option for septage treatment, study on social acceptance of septage-oriented compost was conducted. A large number of interviewed households accepted septage-oriented compost (more than 80%) while a small number of them still concerned about hygiene of compost products. Residents stay closed to agriculture showed less concern about hygiene of compost made from septage while urban citizens had more concern about pathogens in compost products. Some households said if compost made from hygienically treated septage, they are willing to accept.

8.2 Recommendations

The study indicated that water consumption and discharge in urban areas of Vietnam have been changing due to various residential lifestyles. Since development of sewerage system requires long duration, septic tanks are still the most popular on-site facilities for pre-treatment of toilet waste and wastewater from households is discharged directly to open water areas in future decades. To protect water environment and prevent potential health risk, some recommendations are listed as follows.

(1) Traditional water-saving manner may conserve more water in with-elderly households but number of those families is decreasing. It is expected that water

saving affected by traditional water practice will be declined gradually. Future design capacity of water supply need to be considered the increased water demand due to the gradual disappearance of traditional water saving practice.

(2) Urban households have their own water consumption pattern and consumption amount varies hourly. This would raise a comprehensive understanding for a design of water distribution.

(3) The septic tanks are important for the pretreatment of toilet waste by reducing solid matter concentration of excreta. However, due to non-desludging, the septic tanks have low treatment efficiency. The septic tanks contributed a large proportion to organic pollution to receiving waters. Effluent from septic tanks and greywater from households contributed large parts of organic and nutrients pollution to a river because the wastewater is mostly discharged directly without treatment. An urgent measure needs to be considered is regular desludging to improve the performance of present septic tanks.

(4) Almost all of households do not understand the role of regular desludging. Dissemination of the importance of frequent desludging to the households; therefore, is needed before desludging strategy designed.

(5) Sludge accumulation rate differs from area to each other. The data obtained in this study can be applied to design desludging frequency.

(6) Most current septic tanks are designed based on practical experience and often have a big size for long retention. This oversized design costs money and practical experience lacks standardized design. Sludge accumulation rate can also be used for proper design of septic tanks.

(7) In addition, sludge accumulation rate can also be used for proper design of septic tanks as Sludge accumulation rate data in this study can be used for the design of desludging frequency for current septic tanks.

(8) When regular desludging is implemented, volume of collected septage is increased as well. The collected septage needs to be treated in an appropriate way to protect environmental sanitation. Since septage composition has a hug variation

and is much affected by desludging frequency, design of septage treatment needs to base on local data and address desludging frequency.

(9) Septage-oriented compost is a suitable way to recycle nutrients. The public show their concern on the hygiene of compost product. To treat septage into compost, proper treatment of not only pathogens but also heavy metals is essential for health safety.

(10) There has been a need of regulating sludge management. For example, regular inspection and examination of septic tanks should be conducted and regular desludging needs to be promoted. It is necessary to assign the clear responsibilities among stakeholders such as households, local government, desludging sectors, *etc.* to comply regulated system.

Further studies

Since water consumption and discharge as well as river loadings were studied on weekdays in this research, the estimated loadings missed a large proportion of residents staying out of the houses. The similar surveys on weekends should be further studied.

Although it was estimated that annual desludging can reduce loads of COD and SS, the actual loads reduction of each septic tank should be monitored to suggest more detailed mitigation measure to improve wastewater management.

Sludge treatment scenarios should be studied considering co-treatment with other waste types such as garbage, sewage sludge.

There should be further studies focusing on the analysis of heavy metals in septage as well as other waste. Not only heavy metals but pathogens also need to be studied. Concentration levels of heavy metals and pathogenic microorganism can be used for the estimation of potential health risk.

APPENDIX

Appendix I (A)

Questionnaire for water consumption and discharge (Chapter 3)

Interviewer:……..……………………………Date………………………………………

Name of interviewee:________________________________	Educational level:________	
Address:_________________	Ward/Commune__________________	District__________
Age:__________________________________	Sex: M/F_____	Occupation:_____________
Relation with household's head:____		

A. GENERAL INFORMATION			
1	Number of members	……… Pers. ( ) Male ( ) Female	
2	Number of members often stay in the house	……….Pers.( ) Male ( ) Female	
3	Age structure	□ <5:…………Pers. □ 5-9:………...Pers. □ 10-19:……..Pers. □ 20-29:……..Pers. □ 30-39:……. Pers.	□ 40-49:…….. ..Pers. □ 50-59:……….Pers. □ 60-69: ………Pers. □ 70:…………..Pers.
B. HOUSE INSTALLATION			
1	Type of house	Own private house □ Rented house □ Not defined □ Shared house □	Apartment □ Single unit house □ Others □ (Indicate)_____________
		Year of construction/rent__________	Number of floors______ Number of rooms______
2	Kitchen	Sink □ Yes □ No	
3	Washing machine	□ Yes Type……….kg □ No	
4	Bathroom	Number of bathrooms_____________________________ Bathtub □ Yes…………Tub (□ Use □ Not use) □ No	

		Shower □ Yes □ No	
5	Toilet	Number of toilets______________ Type: Pour-flush □ Cister-flush □ Others(indicate) □	Flushing volume:____L Water saving cistern □ Yes (L/ L) □ No

C. WATER USING BEHAVIUORS

1. Washing style: □ By machine □ By hands
2. Bathing: □ Use bath-tub □ Use shower □ Use bucket
3. Kitchening: □ Use kitchen sink □ Use plastic basin

D. SEPTIC TANK- O&M

1	Septic tank	Type □ Rectangular □ Cylindrical □ Others No. of chambers □ One □ Two □ Three Influent □ Black □ Combined with greywater Materials □Concrete □Others (Indicate)________________________ Chemical use □ Cleaning (Indicate)___________________ □ Septic tank performance enhancement (Indicate)_______ Years of construction_________ (LxWxH) = _________ Number of emptying _______times Latest desludging___________________ Desludging fee:___________ □ Expensive □ Medium □ Cheap Way to contact the service___________________________
2	Septage	Do you know to which the septage is dumped into? □ Yes (Indicate)___________________________ □ No Do you know desludging helps improve septic tank performance? □ Yes □ No If regular desludging is required, are you willing to comply with? □ Yes (Indicate)_________________________________ □ No (Indicate)__________________________________ Your opinion about septage-made compost?

		□ Yes, positively (Indicate which level? Vegetable, Fruit trees, bonsai, roadside trees)________________________ ____ □ No (Indicate reason)____________________________ ____	
E.	**WATER USE**		
1	Water supply	□ (1) Piped water □ (2) Public water □ (3) Private grilled well □ (4) Protected dug well □ (5) Unprotected dug well □ (6) Unprotected mountain creek □ (7) Rain water □ (8) Others	□ Drinking ( ) □ Cooking ( ) □ Showering ( ) □ Laundry ( ) □ Others ( )
2	Water discharge	Grey water □ Drainage □ Open water bodies □ Others (Indicate) Septic tank effluent connection □ Drainage □ Open water bodies □ Soakpit □ Others (Indicate)	

Appendix I (B)

Hourly water consumption of ten modern apartments (Chapter 3)

Water consumption (L/cap/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	2	4	6	2	0	2	0	0	0	0
1-2 AM	0	4	0	0	0	0	5	8	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	8	0	0	0	0	0	0	0
5-6 AM	3	0	0	2	4	8	0	4	0	2
6-7 AM	2	9	3	3	26	4	7	0	0	3
7-8 AM	8	8	5	11	0	0	5	20	27	13
8-9 AM	3	0	14	8	0	0	0	30	14	19
9-10 AM	0	0	3	0	0	0	2	2	15	0
10-11 AM	6	0	10	13	0	0	5	18	8	0
11AM-12 PM	4	0	3	11	0	0	0	0	12	3
12-1 PM	5	0	13	9	0	0	5	9	8	0
1-2 PM	3	0	0	5	0	0	12	6	15	0
2-3 PM	2	0	0	0	0	0	0	8	12	6
3-4 PM	4	0	3	0	0	0	2	2	12	7
4-5 PM	4	0	3	2	13	0	9	2	7	3
5-6 PM	6	10	4	13	0	0	5	3	0	8
6-7 PM	13	18	13	22	25	19	13	16	33	23
7-8 PM	3	51	11	15	38	10	16	13	45	3
8-9 PM	27	6	20	28	8	6	30	4	13	0
9-10 PM	23	8	6	7	13	5	9	47	0	17
10-11 PM	4	12	0	3	5	6	6	26	0	2
11 PM-12 AM	6	5	0	2	3	3	10	3	4	2
0-1 AM	3	0	5	2	0	0	1	0	0	0
1-2 AM	0	0	0	0	0	0	4	10	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	4	0	0	0	0	0	0	0
5-6 AM	1	0	0	2	3	4	0	3	0	2
6-7 AM	2	9	3	2	11	6	1	0	0	3
7-8 AM	7	8	6	10	0	0	10	23	15	14
8-9 AM	6	0	9	5	0	0	0	25	12	21
9-10 AM	0	0	3	0	0	0	1	2	14	0
10-11 AM	6	0	11	12	0	0	3	21	10	0
11AM-12 PM	4	0	4	7	0	0	0	0	14	3
12-1 PM	5	0	10	10	0	0	4	12	9	0
1-2 PM	3	0	0	7	0	0	14	5	15	0
2-3 PM	2	0	0	0	0	0	0	8	1	8
3-4 PM	4	0	3	0	0	0	2	2	16	8
4-5 PM	4	0	3	3	18	0	6	2	8	3
5-6 PM	6	10	6	16	0	0	9	6	0	9
6-7 PM	27	53	11	26	15	26	13	19	27	21
7-8 PM	30	11	15	13	42	9	17	15	42	2
8-9 PM	4	5	30	32	23	13	33	5	18	0
9-10 PM	3	8	5	11	13	8	12	52	0	20
10-11 PM	4	12	0	3	5	6	11	29	0	3
11 PM-12 AM	6	8	0	2	3	3	10	4	4	2

Appendix I (C1)

Checklist for water consuming activities (Chapter 3)

Please give one slash when the below activities happen at the respective time. Do not forget indicate which other activities are

Time	Hygiene	Toilet use	Bathing/showering	Laundry	Cooking	Dish washing	Others
0-1 AM							
1-2 AM							
2-3 AM							
3-4 AM							
4-5 AM							
5-6 AM							
6-7 AM							
7-8 AM							
8-9 AM							
9-10 AM							
10-11 AM							
11AM-12 PM							
12-1PM							
1-2 PM							
2-3 PM							
3-4 PM							
4-5 PM							
5-6 PM							
6-7 PM							
7-8 PM							
8-9 PM							
9-10 PM							
10-11 PM							
11 PM-12 AM							

Appendix I (C2)

Hourly water-consuming activities of 10 HHs in modern apartments (Chapter 3)

Hygienic practice of a household (happening time/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	1	1	1	1	0	1	1	0	0	0
1-2 AM	0	1	0	0	0	0	2	2	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	1	0	0	0	0	0	0	0
5-6 AM	1	0	0	1	2	2	0	0	0	1
6-7 AM	1	1	1	1	2	2	0	0	0	1
7-8 AM	1	1	2	1	0	0	0	2	2	3
8-9 AM	1	0	1	0	0	0	1	2	2	1
9-10 AM	0	0	1	0	0	0	1	0	0	0
10-11 AM	0	0	0	2	0	0	1	2	0	0
11AM-12 PM	0	0	1	1	0	0	0	0	0	0
12-1 PM	2	0	0	1	0	0	1	0	1	0
1-2 PM	1	0	0	1	0	0	1	1	0	0
2-3 PM	0	0	0	0	0	0	0	1	0	1
3-4 PM	0	0	1	0	0	0	0	0	0	0
4-5 PM	0	0	1	1	1	0	2	1	0	2
5-6 PM	1	0	1	1	0	0	0	0	0	1
6-7 PM	0	0	0	0	1	1	1	0	0	0
7-8 PM	1	1	0	0	2	2	1	1	0	2
8-9 PM	0	0	0	1	1	1	2	0	2	1
9-10 PM	2	0	0	0	0	0	1	0	0	2
10-11 PM	2	3	0	2	2	1	2	0	0	1
11 PM-12 AM	2	0	0	0	2	1	2	1	2	2
0-1 AM	1	0	2	1	0	0	1	0	0	0
1-2 AM	0	0	0	0	0	0	1	1	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	1	0	0	0	0	0	0	0
5-6 AM	1	0	0	1	1	2	0	0	0	2
6-7 AM	1	4	1	1	3	2	0	0	0	3
7-8 AM	1	4	2	0	0	0	2	1	2	0
8-9 AM	1	0	1	0	0	0	1	2	2	1
9-10 AM	0	0	1	0	0	0	0	0	0	0
10-11 AM	0	0	0	1	0	0	1	1	0	0
11AM-12 PM	0	0	0	1	0	0	0	0	0	1
12-1 PM	2	0	0	1	0	0	2	1	0	0
1-2 PM	1	0	0	0	0	0	2	0	0	0
2-3 PM	0	0	0	0	0	0	0	1	0	0
3-4 PM	0	0	0	0	0	0	0	1	0	0
4-5 PM	0	0	1	0	2	0	0	0	1	1
5-6 PM	0	1	1	0	0	0	0	1	0	1
6-7 PM	0	1	0	0	0	1	0	0	0	0
7-8 PM	1	0	0	0	0	2	1	1	0	1
8-9 PM	0	1	0	2	0	0	3	2	2	0
9-10 PM	1	0	2	1	1	0	2	0	1	1
10-11 PM	0	0	0	1	2	1	0	1	0	2
11 PM-12 AM	1	1	0	1	1	0	1	1	2	2

Appendix I (C3)

Hourly water-consuming activities of 10 HHs in modern apartments (Chapter 3)

Toilet use of a household (happening time/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	1	1	2	0	0	1	0	0	0	0
1-2 AM	0	1	0	1	0	0	2	2	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	1	0	0	0	0	0	0	0
5-6 AM	1	0	0	0	2	2	0	1	0	2
6-7 AM	1	2	1	2	2	2	3	0	0	1
7-8 AM	3	1	2	1	0	0	2	2	2	2
8-9 AM	1	0	1	1	0	0	0	2	2	1
9-10 AM	0	0	1	1	0	0	1	1	0	0
10-11 AM	0	0	1	0	0	0	1	2	1	0
11AM-12 PM	2	0	1	2	0	0	0	0	1	1
12-1 PM	1	0	1	3	0	0	2	2	2	0
1-2 PM	1	0	0	2	0	0	1	1	1	0
2-3 PM	1	0	0	1	0	0	0	1	0	1
3-4 PM	2	0	1	0	0	0	0	0	0	1
4-5 PM	2	0	1	0	1	0	2	0	0	2
5-6 PM	0	1	1	1	0	0	2	0	0	1
6-7 PM	0	1	3	2	2	2	4	1	2	0
7-8 PM	1	1	1	3	2	2	3	0	1	2
8-9 PM	0	2	3	2	1	1	2	2	3	1
9-10 PM	3	2	1	2	2	3	1	1	0	3
10-11 PM	1	2	0	0	0	1	1	0	0	2
11 PM-12 AM	2	2	0	2	1	2	2	2	2	2
0-1 AM	1	0	2	1	0	0	0	0	0	0
1-2 AM	0	0	0	1	0	0	2	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	1	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	1	2	0	2	0	2
6-7 AM	1	2	1	2	3	2	1	0	0	3
7-8 AM	2	1	2	1	0	0	3	1	2	1
8-9 AM	1	0	1	1	0	0	0	0	2	1
9-10 AM	0	0	1	1	0	0	1	7	0	0
10-11 AM	0	0	1	0	0	0	0	2	0	0
11AM-12 PM	2	0	2	2	0	0	0	0	0	2
12-1 PM	1	0	3	3	0	0	2	2	0	0
1-2 PM	1	0	0	2	0	0	1	0	0	0
2-3 PM	1	0	0	1	0	0	0	2	0	1
3-4 PM	2	0	1	0	0	0	2	0	0	2
4-5 PM	2	0	1	0	2	0	1	0	2	1
5-6 PM	0	2	1	1	0	0	2	2	0	3
6-7 PM	0	1	3	1	1	2	1	1	2	2
7-8 PM	1	1	2	3	1	1	1	2	1	1
8-9 PM	1	2	3	2	2	1	2	0	2	0
9-10 PM	1	1	2	3	1	2	1	2	0	3
10-11 PM	2	2	0	3	2	0	2	1	0	2
11 PM-12 AM	2	1	0	2	1	1	2	2	2	2

Appendix I (C4)

Hourly water-consuming activities of 10 HHs in modern apartments (Chapter 3)

Bathing/showering of a household (happening time/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	1	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	1	0	0	0	0
6-7 AM	0	0	0	0	1	0	1	0	0	1
7-8 AM	0	0	0	0	0	0	0	0	2	0
8-9 AM	0	0	1	0	0	0	0	1	0	2
9-10 AM	0	0	0	1	0	0	0	0	0	0
10-11 AM	0	0	0	0	0	0	0	0	0	0
11AM-12 PM	0	0	0	0	0	0	0	0	0	0
12-1 PM	0	0	1	0	0	0	0	0	0	0
1-2 PM	0	0	0	0	0	0	0	0	1	0
2-3 PM	0	0	0	0	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	1	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	1	1	0	1	0	1	0	1	1	2
7-8 PM	0	1	0	1	2	1	0	0	1	0
8-9 PM	0	0	2	1	0	1	3	0	1	0
9-10 PM	2	0	1	0	1	0	1	1	0	2
10-11 PM	0	0	0	1	0	1	0	2	0	0
11 PM-12 AM	0	0	0	0	0	0	1	0	0	0
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	0	0	0
6-7 AM	0	0	0	0	1	0	0	0	0	0
7-8 AM	0	0	0	0	0	0	0	1	0	0
8-9 AM	0	0	1	1	0	0	0	0	0	0
9-10 AM	0	0	0	0	0	0	0	0	0	0
10-11 AM	0	0	0	0	0	0	0	0	0	0
11AM-12 PM	0	0	0	0	0	0	0	0	0	0
12-1 PM	0	0	0	0	0	0	0	1	0	0
1-2 PM	0	0	0	0	0	0	1	0	0	0
2-3 PM	0	0	0	0	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	0	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	1	2	1	1	0	2	0	0	2	2
7-8 PM	1	0	1	2	2	1	1	1	2	0
8-9 PM	1	0	1	0	1	0	1	0	0	0
9-10 PM	0	0	0	1	1	0	1	2	0	2
10-11 PM	0	0	0	0	0	1	1	1	0	0
11 PM-12 AM	0	0	0	0	0	0	1	0	0	0

Appendix I (C5)

Hourly water-consuming activities of 10 HHs in modern apartments (Chapter 3)

Laundry of a household (happening time/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	0	0	0
6-7 AM	0	0	0	0	1	0	0	0	0	0
7-8 AM	0	0	0	1	0	0	0	1	0	1
8-9 AM	0	0	0	0	0	0	0	0	0	0
9-10 AM	0	0	0	0	0	0	0	0	1	0
10-11 AM	0	0	0	0	0	0	0	0	0	0
11AM-12 PM	0	0	0	0	0	0	0	0	0	0
12-1 PM	0	0	0	0	0	0	0	0	0	0
1-2 PM	0	0	0	0	0	0	1	0	0	0
2-3 PM	0	0	0	0	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	0	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	0	0	0	0	1	0	0	0	1	1
7-8 PM	0	1	0	0	0	0	0	0	0	0
8-9 PM	1	0	0	0	0	0	1	0	0	0
9-10 PM	0	0	0	1	0	0	0	1	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	0	0	0
6-7 AM	0	0	0	0	0	0	0	0	0	0
7-8 AM	0	0	0	0	0	0	0	1	0	0
8-9 AM	0	0	0	0	0	0	0	0	0	1
9-10 AM	0	0	0	0	0	0	0	0	0	0
10-11 AM	0	0	0	0	0	0	0	0	0	0
11AM-12 PM	0	0	0	0	0	0	0	0	0	0
12-1 PM	0	0	0	0	0	0	0	0	0	0
1-2 PM	0	0	0	0	0	0	0	0	0	0
2-3 PM	0	0	0	0	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	0	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	0	1	0	0	0	0	0	0	0	1
7-8 PM	1	0	0	0	1	0	0	0	0	0
8-9 PM	0	0	1	0	0	1	1	0	1	0
9-10 PM	0	0	0	1	0	0	0	1	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0

Appendix I (C6)

Hourly water-consuming activities of 10 HHs in modern apartments (Chapter 3)

Cooking of a household (happening time/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	1	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	1	0	0
6-7 AM	0	0	0	0	0	0	1	0	0	0
7-8 AM	0	1	0	0	0	0	1	0	1	1
8-9 AM	0	0	0	0	0	0	0	0	0	0
9-10 AM	0	0	0	0	0	0	0	0	0	0
10-11 AM	1	0	1	0	0	0	1	1	1	0
11AM-12 PM	0	0	0	1	0	0	0	0	0	1
12-1 PM	0	0	0	0	0	0	0	0	0	0
1-2 PM	0	0	0	0	0	0	0	0	0	0
2-3 PM	0	0	0	0	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	0	0	1	0	0	0
5-6 PM	1	1	1	1	1	0	1	1	0	1
6-7 PM	1	0	0	0	0	1	0	1	1	1
7-8 PM	0	0	0	0	0	0	0	0	0	0
8-9 PM	0	0	0	0	0	0	0	0	0	0
9-10 PM	0	0	0	0	0	0	0	0	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	0	0	0
6-7 AM	0	0	0	1	0	1	0	0	0	0
7-8 AM	0	0	0	1	0	0	1	0	1	1
8-9 AM	0	0	0	0	0	0	0	0	0	0
9-10 AM	0	0	0	1	0	0	0	0	0	0
10-11 AM	1	0	1	0	0	0	1	1	0	0
11AM-12 PM	0	0	0	1	0	0	0	0	0	1
12-1 PM	0	0	0	0	0	0	0	0	0	0
1-2 PM	0	0	0	0	0	0	0	0	0	0
2-3 PM	0	0	0	1	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	1	0	0	1	1	0
5-6 PM	1	1	1	0	0	0	1	0	0	1
6-7 PM	1	0	0	1	0	1	0	1	0	0
7-8 PM	0	0	0	0	0	0	0	0	0	0
8-9 PM	0	0	0	0	0	0	0	0	0	0
9-10 PM	0	0	0	0	0	0	0	0	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0

Appendix I (C7)

Hourly water-consuming activities of 10 HHs in modern apartments (Chapter 3)

Dish washing of a household (happening time/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	1	0	0
6-7 AM	0	0	0	0	0	0	0	0	0	0
7-8 AM	0	0	0	0	0	0	0	0	1	1
8-9 AM	0	0	0	0	0	0	1	0	0	0
9-10 AM	0	0	0	0	0	0	0	0	0	0
10-11 AM	0	0	0	0	0	0	0	0	0	0
11AM-12 PM	1	0	1	1	0	0	0	1	1	1
12-1 PM	0	0	0	0	0	0	0	0	0	0
1-2 PM	0	0	0	0	0	0	0	0	0	0
2-3 PM	0	0	0	0	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	0	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	0	1	0	1	1	0	1	0	0	0
7-8 PM	1	0	1	0	0	1	0	1	1	1
8-9 PM	0	0	0	0	0	0	0	0	0	0
9-10 PM	0	0	0	0	0	0	0	0	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	0	0	0
6-7 AM	0	0	0	0	0	0	0	0	0	0
7-8 AM	0	0	0	1	0	1	0	0	0	0
8-9 AM	0	0	0	0	0	0	1	0	1	1
9-10 AM	0	0	0	0	0	0	0	0	0	0
10-11 AM	0	0	1	0	0	0	0	0	0	0
11AM-12 PM	1	0	0	0	0	0	0	0	0	0
12-1 PM	0	0	0	1	0	0	0	1	0	0
1-2 PM	0	0	0	0	0	0	0	0	0	1
2-3 PM	0	0	0	0	0	0	0	0	0	0
3-4 PM	0	0	0	0	0	0	0	0	0	0
4-5 PM	0	0	0	0	1	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	0	1	1	0	0	0	1	0	1	1
7-8 PM	1	0	0	0	0	1	0	1	0	0
8-9 PM	0	0	0	1	0	0	0	0	0	0
9-10 PM	0	0	0	0	0	0	0	0	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0

Appendix I (C8)

Hourly water-consuming activities of 10 HHs in modern apartments (Chapter 3)

Other activities (house cleaning, bonsai watering) of a household (happening time/hour)

Time	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8	HH9	HH10
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	0	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	0	0	0
6-7 AM	0	0	0	0	0	0	0	0	0	0
7-8 AM	0	0	0	0	0	0	0	0	0	0
8-9 AM	0	0	1	0	0	0	0	0	0	0
9-10 AM	0	0	0	0	0	0	0	0	0	0
10-11 AM	0	0	0	0	0	0	0	0	0	0
11AM-12 PM	0	0	0	0	0	0	0	0	1	0
12-1 PM	0	0	0	0	0	0	0	1	0	0
1-2 PM	0	0	0	0	0	0	0	0	1	0
2-3 PM	0	0	0	0	0	0	0	0	0	1
3-4 PM	0	0	0	0	0	0	0	0	0	1
4-5 PM	0	0	0	0	0	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	0	0	0	0	0	0	0	0	0	0
7-8 PM	0	0	0	0	0	0	0	1	0	0
8-9 PM	0	0	0	0	0	0	0	0	0	0
9-10 PM	0	0	0	0	0	0	0	0	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0
0-1 AM	0	0	0	0	0	0	0	0	0	0
1-2 AM	0	0	0	0	0	0	0	0	1	0
2-3 AM	0	0	0	0	0	0	0	0	0	0
3-4 AM	0	0	0	0	0	0	0	0	0	0
4-5 AM	0	0	0	0	0	0	0	0	0	0
5-6 AM	0	0	0	0	0	0	0	0	0	0
6-7 AM	0	0	0	0	0	0	0	0	0	0
7-8 AM	0	0	0	0	0	0	1	1	0	0
8-9 AM	0	0	0	0	0	0	0	0	0	1
9-10 AM	0	0	0	0	0	0	0	0	0	0
10-11 AM	0	0	0	0	0	0	0	0	0	0
11AM-12 PM	0	0	0	0	0	0	0	0	0	0
12-1 PM	0	0	0	0	0	0	0	0	0	0
1-2 PM	0	0	0	0	0	0	0	1	0	0
2-3 PM	0	0	0	0	0	0	0	0	0	1
3-4 PM	0	0	0	0	0	0	0	0	0	1
4-5 PM	0	0	0	0	0	0	0	0	0	0
5-6 PM	0	0	0	0	0	0	0	0	0	0
6-7 PM	0	0	0	0	0	0	0	0	1	0
7-8 PM	0	0	0	0	0	0	0	0	0	0
8-9 PM	0	0	0	0	0	0	0	0	0	0
9-10 PM	0	0	0	0	0	0	0	0	0	0
10-11 PM	0	0	0	0	0	0	0	0	0	0
11 PM-12 AM	0	0	0	0	0	0	0	0	0	0

Appendix I (D)

Quality of household wastewater (00:00 January 7, 2013 – 24:00 January 7, 2013) (Chapter 3)

Time	COD_{Cr} (mg/L)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	381	251	272	379	256	308	66
3-4 AM	272	379	304	395	380	346	55
6-7 AM	493	260	495	447	314	402	108
9-10 AM	495	447	596	505	550	519	57
12-1 PM	753	633	796	660	405	649	152
3-4 PM	796	660	824	789	600	734	98
6-7 PM	400	298	350	476	353	375	67
9-10 PM	350	476	408	450	486	434	56

Time	BOD_5 (mg/L)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	140	60	120	100	80	100	32
3-4 AM	70	150	90	160	150	124	41
6-7 AM	200	80	280	180	240	196	75
9-10 AM	230	190	310	240	190	232	49
12-1 PM	420	400	440	420	360	408	30
3-4 PM	460	350	480	450	310	410	75
6-7 PM	160	90	120	220	120	142	50
9-10 PM	120	210	170	200	230	186	43

Time	TKN (mg/L)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	49.0	44.8	65.1	48.3	51.8	51.8	7.8
6-7 AM	49.7	45.5	67.9	50.4	55.3	53.8	8.6
12-1 PM	67.2	58.1	72.8	65.8	62.3	65.3	5.5
6-7 PM	65.1	45.5	62.0	51.8	55.3	56.0	7.9

Time	TP (mg/L)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	4.9	4.1	7.0	7.4	5.9	5.9	1.4
6-7 AM	7.5	4.6	9.3	7.7	7.2	7.3	1.7
12-1 PM	9.6	8.1	11.1	9.9	10.3	9.8	1.1
6-7 PM	8.1	10.0	9.2	9.1	8.6	9.0	0.7

Time	SS (mg/L)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	50	90	30	49	69	58	23
6-7 AM	74	57	74	45	84	67	16
12-1 PM	97	204	82	98	98	116	50
6-7 PM	90	78	69	86	71	79	9

Time	VSS (mg/L)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	41	50	21	32	12	31	15
6-7 AM	62	44	55	18	50	46	17
12-1 PM	92	157	68	81	64	92	38
6-7 PM	86	66	59	55	64	66	12

Time	*E. Coli* (CFU/100mL)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	3.2E+05	3.2E+05	2.5E+05	2.7E+05	6.3E+05	3.6E+05	1.6E+05
6-7 AM	2.2E+05	2.2E+05	1.5E+05	3.1E+05	8.6E+05	3.5E+05	2.9E+05
12-1 PM	2.2E+04	1.1E+05	7.6E+04	4.8E+05	1.0E+06	3.4E+05	4.1E+05
6-7 PM	1.1E+05	2.5E+05	9.0E+04	4.2E+05	7.8E+05	3.3E+05	2.8E+05

Time	Total Coliform (CFU/100mL)						
	House 1	House 2	House 3	House 4	House 5	Average	S.D.
0-1 AM	4.6E+05	9.5E+05	3.1E+05	3.8E+05	6.5E+05	5.5E+05	2.6E+05
6-7 AM	5.4E+05	6.2E+05	2.4E+05	4.0E+05	9.1E+05	5.4E+05	2.5E+05
12-1 PM	3.0E+05	3.7E+05	2.0E+05	5.7E+05	1.0E+06	4.9E+05	3.3E+05
6-7 PM	3.6E+05	4.9E+05	2.1E+05	4.5E+05	8.0E+05	4.6E+05	2.2E+05

Appendix II (A)

River flow measurement at five sub-sections at the inlet of the watershed (00:00 January 21, 2013 to 24:00 January 22, 2013) (Chapter 4)

Time	P1		P2		P3		P4	
	Depth (m)	Velocity (cm/s)	Depth (m)	Velocity (cm/s)	Depth (m)	Velocity (cm/s)	Depth (m)	Velocity (cm/s)
0-1 AM	0.29	24.9	0.31	19.1	0.29	6.1	0.29	7.1
1-2 AM	0.29	26.4	0.30	13.0	0.30	6.5	0.29	6.9
2-3 AM	0.30	25.9	0.29	18.2	0.29	6.4	0.30	9.7
3-4 AM	0.30	22.7	0.29	11.1	0.29	7.2	0.28	8.3
4-5 AM	0.29	27.1	0.29	18.6	0.29	6.3	0.30	8.0
5-6 AM	0.28	17.4	0.29	8.9	0.29	5.7	0.29	7.3
6-7 AM	0.30	16.1	0.29	16.3	0.30	7.9	0.30	12.2
7-8 AM	0.29	9.4	0.29	13.9	0.31	12.3	0.31	6.8
8-9 AM	0.30	7.9	0.29	22.8	0.31	8.4	0.30	10.7
9-10 AM	0.30	12.7	0.29	22.7	0.30	7.5	0.30	7.5
10-11 AM	0.30	10.5	0.29	8.7	0.31	13.3	0.30	9.1
11AM-12 PM	0.30	11.1	0.30	9.7	0.32	9.8	0.30	8.4
12-1 PM	0.30	17.0	0.29	10.9	0.29	8.0	0.32	9.3
1-2 PM	0.29	8.1	0.33	12.0	0.30	21.3	0.30	8.3
2-3 PM	0.30	8.7	0.29	13.4	0.29	10.6	0.29	8.1
3-4 PM	0.30	11.4	0.29	19.9	0.32	35.6	0.30	6.9
4-5 PM	0.29	12.8	0.30	20.6	0.31	6.2	0.30	11.8
5-6 PM	0.30	17.3	0.31	10.4	0.32	20.0	0.30	8.2
6-7 PM	0.30	26.0	0.32	18.0	0.32	19.3	0.31	5.6
7-8 PM	0.32	29.7	0.29	9.3	0.30	14.9	0.31	6.9
8-9 PM	0.32	18.2	0.32	17.7	0.31	14.8	0.29	7.6
9-10 PM	0.33	17.5	0.34	11.4	0.30	7.8	0.28	10.4
10-11 PM	0.29	26.5	0.31	15.0	0.32	7.3	0.31	8.1
11 PM-12 AM	0.32	17.3	0.31	11.9	0.31	9.5	0.30	10.9
0-1 AM	0.31	5.6	0.29	12.1	0.29	7.9	0.31	11.0
1-2 AM	0.29	10.3	0.29	10.7	0.30	15.3	0.32	12.0
2-3 AM	0.29	6.5	0.31	9.4	0.30	14.4	0.32	9.3
3-4 AM	0.31	5.4	0.29	5.8	0.30	9.1	0.30	9.9
4-5 AM	0.30	6.0	0.29	13.9	0.34	8.8	0.31	7.3
5-6 AM	0.32	5.8	0.31	13.3	0.29	8.7	0.31	7.5
6-7 AM	0.29	6.9	0.30	9.4	0.30	9.2	0.30	8.2
7-8 AM	0.30	18.1	0.31	19.5	0.30	10.3	0.29	7.4
8-9 AM	0.34	8.0	0.29	9.8	0.29	15.1	0.29	9.8
9-10 AM	0.29	13.4	0.34	19.1	0.31	10.2	0.30	8.5
10-11 AM	0.36	19.1	0.30	13.4	0.30	9.1	0.29	11.3
11AM-12 PM	0.33	9.9	0.30	39.0	0.29	11.3	0.29	11.1
12-1 PM	0.29	16.1	0.33	30.9	0.30	7.5	0.29	8.2
1-2 PM	0.29	6.4	0.31	45.2	0.31	8.2	0.29	7.5
2-3 PM	0.30	14.1	0.30	10.2	0.30	11.7	0.30	9.2
3-4 PM	0.31	26.1	0.30	8.2	0.29	13.7	0.30	8.0
4-5 PM	0.31	16.3	0.29	7.3	0.30	7.3	0.32	7.9
5-6 PM	0.30	28.3	0.28	6.7	0.29	16.0	0.32	7.7
6-7 PM	0.29	30.8	0.30	5.4	0.30	9.8	0.29	11.2
7-8 PM	0.31	26.8	0.29	10.9	0.30	9.7	0.31	7.1
8-9 PM	0.29	30.4	0.29	12.6	0.30	10.4	0.31	11.9
9-10 PM	0.29	25.0	0.30	5.5	0.29	10.8	0.29	9.0
10-11 PM	0.29	29.1	0.31	14.5	0.32	12.4	0.31	6.6
11 PM-12 AM	0.30	20.3	0.29	6.1	0.30	8.4	0.29	7.0

Appendix II (B)

River flow measurement at six sub-sections at the inlet of the watershed (00:00 January 24, 2013 - 24:00 January 25, 2013) (Chapter 4).

Time	Point 1		Point 2		Point 3		Point 4		Point 5	
	Depth (m)	Velocity (cm/s)	Depth (m)	Velocity (cm/s)	Depth (m)	Velocity (cm/s)	Depth (m)	Velocity (cm/s)	Depth (m)	Velocity (cm/s)
0-1 AM	1.87	9.5	3.12	38.6	3.06	9.6	1.96	14.1	1.32	8.9
1-2 AM	1.93	13.9	3.09	37.6	3.08	9.0	1.95	11.7	1.31	7.6
2-3 AM	1.94	9.0	3.02	38.9	3.07	9.3	1.95	12.7	1.34	7.8
3-4 AM	1.98	12.9	2.68	40.3	3.06	5.7	1.95	13.4	1.31	5.8
4-5 AM	1.94	10.8	3.01	38.8	3.06	7.6	1.96	9.7	1.32	8.9
5-6 AM	1.92	11.7	3.18	39.1	3.03	9.1	1.95	13.5	1.32	10.0
6-7 AM	1.89	6.6	2.66	32.3	3.04	9.1	1.97	11.6	1.32	9.8
7-8 AM	1.94	8.9	2.94	34.0	3.04	10.7	1.97	12.6	1.30	8.9
8-9 AM	1.99	5.9	2.97	28.3	3.02	6.7	1.95	13.2	1.27	6.8
9-10 AM	2.00	7.6	2.98	24.9	3.03	9.4	1.95	10.0	1.31	9.7
10-11 AM	1.94	22.8	2.50	7.0	3.00	5.5	1.87	9.3	1.29	4.3
11AM-12 PM	1.86	20.7	2.55	10.3	3.01	8.0	1.73	6.4	1.33	8.7
12-1 PM	1.90	11.9	2.68	10.3	3.01	5.5	1.94	4.6	1.31	3.7
1-2 PM	1.90	15.8	2.58	12.1	2.96	8.1	1.77	10.6	1.51	5.7
2-3 PM	1.97	13.8	2.54	26.9	3.01	6.1	1.75	4.8	1.41	2.3
3-4 PM	2.03	10.8	2.56	29.9	3.16	8.8	1.67	2.9	1.31	3.8
4-5 PM	1.96	22.0	2.60	13.5	3.20	7.1	1.43	5.8	1.39	8.6
5-6 PM	1.90	17.6	2.61	30.6	3.19	7.2	1.75	4.6	1.40	7.4
6-7 PM	2.45	23.6	3.24	6.8	3.22	5.0	1.62	6.8	1.36	6.7
7-8 PM	2.20	18.4	3.04	16.5	3.19	6.1	1.68	7.3	1.39	5.4
8-9 PM	2.00	13.2	3.22	26.9	3.21	5.7	1.83	8.8	1.49	6.8
9-10 PM	1.99	16.6	3.21	32.5	3.18	4.9	1.84	8.9	1.45	5.5
10-11 PM	2.03	25.6	3.11	9.4	3.14	7.7	1.81	6.7	1.43	3.4
11 PM-12 AM	2.12	30.7	3.15	9.2	3.21	7.6	1.93	3.4	1.51	6.0
0-1 AM	2.05	28.0	3.17	11.6	3.20	6.9	1.97	5.3	1.48	6.4
1-2 AM	1.98	32.0	3.14	15.3	3.26	3.0	2.07	2.8	1.50	5.8
2-3 AM	2.01	28.8	3.21	17.9	3.23	5.8	1.98	4.1	1.52	5.2
3-4 AM	1.97	25.2	3.22	16.7	3.25	6.5	2.01	4.4	1.49	4.6
4-5 AM	1.99	19.5	3.25	16.6	3.23	3.5	1.98	3.3	1.48	2.6
5-6 AM	1.98	19.2	3.25	17.5	3.25	2.9	1.96	3.0	1.50	2.0
6-7 AM	2.01	20.9	3.26	12.6	3.18	3.9	1.88	4.8	1.50	2.4
7-8 AM	2.37	10.3	3.29	8.5	3.20	8.8	1.86	7.5	1.46	8.9
8-9 AM	2.11	27.5	3.30	6.3	3.10	8.6	1.86	6.5	1.44	7.9
9-10 AM	2.12	22.6	3.31	7.5	3.15	7.8	1.87	6.9	1.54	7.9
10-11 AM	2.05	32.1	3.33	11.1	3.12	8.1	1.85	8.5	1.46	8.6
11AM-12 PM	2.02	16.9	3.35	8.5	3.24	8.8	1.94	6.3	1.53	9.3
12-1 PM	2.08	25.3	3.32	5.0	3.24	9.8	1.89	10.5	1.43	3.7
1-2 PM	2.02	33.0	3.30	10.1	3.18	11.2	1.92	8.7	1.47	7.9
2-3 PM	2.00	30.8	3.30	8.6	3.22	9.9	1.87	9.5	1.57	4.8
3-4 PM	2.00	7.0	3.08	3.9	3.04	2.8	1.87	5.8	1.89	46.0
4-5 PM	1.91	9.0	3.12	33.3	3.08	13.0	1.78	10.3	1.20	6.8
5-6 PM	1.88	7.4	3.25	33.8	2.89	10.4	1.91	16.5	1.38	9.9
6-7 PM	1.92	10.6	3.11	28.5	3.02	12.7	1.90	13.5	1.40	11.1
7-8 PM	1.97	10.2	3.17	34.4	3.02	14.5	1.91	13.2	1.38	12.8
8-9 PM	1.84	6.1	3.16	32.4	3.01	10.5	1.91	12.8	1.33	11.0
9-10 PM	1.89	9.1	3.11	41.9	2.98	13.1	1.92	14.1	1.36	9.6
10-11 PM	1.88	9.6	3.28	29.5	3.05	11.9	1.89	7.7	1.35	5.9
11 PM-12 AM	1.91	9.6	3.06	32.0	3.07	11.3	1.96	13.8	1.34	7.9

Appendix II (C)

Total concentrations of COD_{Cr}, BOD_5, TKN, and TP of West Lake water (February 27, 2013) (Chapter 4)

Time	COD_{Cr} (mg/L)	BOD_5 (mg/L)	SS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)
9:50	94	40	17	15	26.46	1.07
13:50	52	40	20	18	36.4	1.04

Dissolved concentrations of COD_{Cr}, BOD_5, TKN, and TP of West Lake (Chapter 4)

Time	COD_{Cr} (mg/L)	BOD_5 (mg/L)	TKN (mg/L)	TP (mg/L)
9:50	38	20	13.76	0.53
13:50	28	20	26.4	0.21

Household wastewater in dissolved concentrations (Chapter 4)

House ID	Time	Soluble concentration (mg/L)			
		$COD_{Cr\text{-}s}$	$BOD_{5\text{-}s}$	TKN_s	$T\text{-}P_s$
House 1	0-1 AM	191	70	24	1
	6-7 AM	222	90	25	2
	12-1 PM	508	252	34	2
	6-7 PM	177	81	38	3
House 2	0-1 AM	138	33	18	1
	6-7 AM	117	36	20	2
	12-1 PM	498	200	25	2
	6-7 PM	246	58	23	5
House 3	0-1 AM	163	72	30	3
	6-7 AM	248	140	34	4
	12-1 PM	743	220	49	5
	6-7 PM	235	103	31	3
House 4	0-1 AM	227	100	23	2
	6-7 AM	224	157	23	3
	12-1 PM	528	324	36	4
	6-7 PM	395	122	26	5
House 5	0-1 AM	55	44	23	2
	6-7 AM	90	120	22	3
	12-1 PM	319	198	34	5
	6-7 PM	177	102	29	3

Appendix III (A)

Questionnaire for structured interview in Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi (Chapter 5)

BẢNG CÂU HỎI KHẢO SÁT
QUESTIONNAIRE SHEET

Người phỏng vấn: Name of interviewer: ____________________
Ngày phỏng vấn: Date of interview: ___/___/2013

☐ Inside watershed
☐ Outside watershed

Họ tên người được phỏng vấn: Full name of the interviewee: ____________________
Tuổi/Age: ________
Giới tính/Sex: ☐ Nam/M ☐ Nữ/F

Nghề nghiệp: Occupation: ____________________
Địa chỉ: Address: thôn Lai Xá, xã Kim Chung, H. Hoài Đức

Quan hệ với chủ hộ: Relationship to the household's head: ____________________

THÔNG TIN CHUNG VỀ HỘ GIA ĐÌNH
Household attribution

1 Số người trong gia đình
No. of people living in the house: ______

2 Số người thường xuyên sử dụng nhà vệ sinh:
No. of people using toilet ______

3 Thành phần giới tính (số lượng):
Sex structure (No. of people): ______ Nam Male ______ Nữ Female

4 Cơ cấu tuổi: Age structure:

☐ < 5 ______ người	☐ 20 - 29 ______ người	☐ 50 - 59 ______ người
☐ 5 - 9 ______ người	☐ 30 - 39 ______ người	☐ 60 - 69 ______ người
☐ 10 - 19 ______ người	☐ 40 - 49 ______ người	☐ > 70 ______ người

5 Nghề nghiệp chính của gia đình:
Main occupation of the household: ____________________

6 Thu nhập hàng tháng của hộ gia đình
Monthly income of the family:
☐ <1.000.000 đồng
☐ 1.000.000 - 2.000.000 đồng
☐ 2.000.000 - 3.000.000 đồng
☐ 3.000.000 - 4.000.000 đồng
☐ 4.000.000 - 5.000.000 đồng
☐ > 5.000.000 đồng

7 Gia đình có chăn nuôi không
Livestock breeding
☐ Có Yes ☐ Không No

8 Nếu có, ghi rõ số lượng
Please indicate no. of livestock
________ lợn
________ gà

THÔNG TIN VỀ NHÀ Ở VÀ CÔNG TRÌNH PHỤ
Housing and water facilities information

8 Loại nhà ở: Type of house: ☐ Nhà tự xây/own-built ☐ Nhà thuê/rent

9 Số tầng No. of floor ______ tầng floor

10 Số phòng ngủ No. of bed-room ______ phòng room

11 Năm xây nhà/Year of construction ________

12 Nếu là nhà thuê, vui lòng trả lời thông tin sau đây:
If the house is rent, please refer these below questions:

12.1 Năm thuê nhà:
Years of house renting: ______ tháng/month

12.2 Khi thuê nhà anh/chị có được bàn giao bản vẽ nhà và bể tự hoại không?
When renting the house, did you receive the technical drawings of the house and/or septic tanks
☐ Có Yes ☐ Không No

13 Bếp/Kitchen

13.1 Số lượng nhà bếp
No. of kitchen

13.2 Nhiên liệu đun nấu
Fuel for cooking
☐ Gas ☐ Than tổ ong/Briquette
☐ Điện ☐ Khác/Other (ghi rõ)
☐ Củi/Firewood

14 Nhà tắm/Bath-room

14.1 Số lượng nhà tắm
No. of bath-room

14.2 Gia đình có vòi hoa sen không ☐ Có ☐ Không
Shower available or not Yes No

14.3 Gia đình có bồn tắm không ☐ Có ☐ Không
Bath-tub avaiable or not Yes No

14.4 Có sử dụng bồn tắm không ☐ Có ☐ Không
Do you use bath-tub? Yes No

15 Máy giặt

15.1 Gia đình có máy giặt không ☐ Có ☐ Không
Washing machine available or not Yes No

15.2 Có sử dụng máy giặt không ☐ Có ☐ Không
Do you use washing machine? Yes No

15.3 Gia đình có giặt bằng tay không ☐ Có ☐ Không
Do you do hand-washing? Yes No

15.4 Số lần giặt
☐ Ngày nào cũng giặt (once every day)
☐ Mỗi ngày giặt 2 lần (twice every day)
☐ Một tuần giặt một lần/Once every week
☐ Một tuần giặt 2 lần/Twice every week
☐ Một tuần giặt 3 lần/Three times every week
☐ 2 tuần giặt một lần
Once every two weeks
☐ 3 tuần giặt một lần
Once every three weeks

16 Nhà vệ sinh/Toilet

16.1 Số lượng nhà vệ sinh
No. of toilet

16.2 Loại xí
Type of sanitation facilities
☐ Xí bệt 1 nấc xả
Normal cistern-flush
☐ Xí bệt 2 nấc xả
Water-saving cistern-flush
☐ Xí ngồi xổm dội nước
Pour-flush

16.3 Thể tích két nước xả
Volume of flushing
Lít (1 nấc xả)
Liter (Normal)
Lít/
Liter/
Lít (2 nấc xả)
Liter (water-saving)

16.4 Nếu dùng xí ngồi xổm dội nước, vui lòng cho biết/Pleas answer the questions below if you use pour flush toilet

Cách xả nước ☐ Dội bằng gáo/By bucket
How to flush ☐ Bằng vòi xả nước/By valve

Số lượng gáo dùng để dội mỗi lần sử dụng/No. of bucket used
☐ 1 gáo ☐ 2 gáo ☐ 3 gáo ☐ 4 gáo ☐ 5 gáo

NGUỒN VÀ CÁCH SỬ DỤNG NƯỚC SINH HOẠT

Domestic water sources and usage

17 Vui lòng đánh dấu nguồn nước sử dụng cho sinh hoạt của gia đình và mục đích sử dụng của nguồn nước đó
Please indicate water sources and the corresponding purposes

Nguồn/Source	Mục đích/Purpose
☐ Nước mưa Rain water	☐ Ăn/Cooking ☐ Uống/Drinking ☐ Tắm/Bathing ☐ Giặt/Laundry ☐ Tưới cây/Gardening ☐ Chăn nuôi/Livestock raising ☐ Khác/Other
☐ Nước giếng khoan Drilled well water	☐ Ăn/Cooking ☐ Uống/Drinking ☐ Tắm/Bathing ☐ Giặt/Laundry ☐ Tưới cây/Gardening ☐ Chăn nuôi/Livestock raising ☐ Khác/Other
☐ Nước giếng làng Public dug well water	☐ Ăn/Cooking ☐ Uống/Drinking ☐ Tắm/Bathing ☐ Giặt/Laundry ☐ Tưới cây/Gardening ☐ Chăn nuôi/Livestock raising ☐ Khác/Other
☐ Nước đóng chai/bình Bottled water	☐ Ăn/Cooking ☐ Uống/Drinking ☐ Tắm/Bathing ☐ Giặt/Laundry ☐ Tưới cây/Gardening ☐ Chăn nuôi/Livestock raising ☐ Khác/Other

18 Vui lòng chỉ ra biện pháp xử lý nước trước khi sử dụng (nếu có)
Please indicate water sources and the corresponding treatment methods

Nguồn/Source	Phương pháp xử lý/Treatment method
☐ Nước mưa Rain water	☐ Đun sôi/Boiling ☐ Hệ thống lọc/Filtration system ☐ Lọc đơn giản/Simple filtration ☐ Khác (ghi rõ)/Other
☐ Nước giếng khoan Drill-well water	☐ Đun sôi/Boiling ☐ Hệ thống lọc/Filtration system ☐ Lọc đơn giản/Simple filtration ☐ Khác (ghi rõ)/Other
☐ Nước giếng làng Dug-well water	☐ Đun sôi/Boiling ☐ Hệ thống lọc/Filtration system ☐ Lọc đơn giản/Simple filtration ☐ Khác (ghi rõ)/Other

QUẢN LÝ CHẤT THẢI HỘ GIA ĐÌNH
Waste and wastewater management

19 Chất thải từ nhà vệ sinh được xả đi đâu ☐ Bể tự hoại ☐ Khác (ghi rõ)
Where do toilet waste go to — Septic tank — Other

20 Nước thải sinh hoạt (tắm, giặt, v.v.) thải đi đâu
Where does grey water go to
☐ Xả trực tiếp ra cống (Directly to drainage) ☐ Xả ra vườn (Home garden)
☐ Xả ra hố ga trước khi ra cống (To man-hole before to drainage) ☐ Xả ra ao (Pond)

21 Nước đầu ra của bể tự hoại thải đi đâu
Where does septic tank effluent go to
☐ Xả trực tiếp ra cống (Directly to drainage) ☐ Xả ra vườn (Home garden)
☐ Xả ra hố ga trước khi ra cống (To man-hole before to drainage) ☐ Xả ra ao (Pond)

21 Rác thải sinh hoạt của gia đình đổ đi đâu
How to dispose domestic waste
☐ Thu gom bởi Công ty Môi trường (By URENCO)
☐ Đổ ra bên ngoài (Open dumping)

22 Rác thải nhà bếp, cơm, rau thừa đổ đi đâu
How to dispose kitchen waste and food leftover
☐ Thu gom bởi Công ty Môi trường (By URENCO)
☐ Đổ ra bên ngoài (Open dumping)
☐ Làm thức ăn chăn nuôi (Livestock breeding)

VẬN HÀNH VÀ QUẢN LÝ BỂ TỰ HOẠI
Septic tank structure and O&M

23 Hình dạng của bể ☐ Bể hình hộp ☐ Bể hình trụ
Shape of septic tank — Rectangular — Cinlyndrical

24 Số ngăn ☐ 1 ☐ 2 ☐ 3
No. of chamber

25 Vật liệu xây bể ☐ Bê tông ☐ Khác (ghi rõ)
Material — Concrete — Other

26 Năm xây bể
Year of construction

27 Vui lòng đánh dấu các chất thải đưa vào bể tự hoại ☐ Chất thải từ xí ☐ Nước tắm, giặt, v.v.
Influent to septic tank — Black water — Grey water

28 Kích thước của bể — Chiều dài m — Chiều rộng m — Chiều sâu m
Volume of septic tank — Length — Width — Depth

29 Gia đình có sử dụng hoá chất để cọ rửa bồn cầu không? Nếu có, vui lòng ghi tên hoá chất sử dụng
Please indicate if you use chemicals for toilet cleaning
☐ Có sử dụng (ghi rõ tên) (Yes (indicate)) ☐ Không sử dụng (No)

30 Gia đình có sử dụng hoá chất làm tăng hiệu quả xử lý cho bể tự hoại không? Nếu có, vui lòng ghi tên
Please indicate if you use chemicals to improve septick tank removal efficiency
☐ Có sử dụng (ghi rõ tên) (Yes (indicate)) ☐ Không sử dụng (No)

31 Bể tự hoại nhà anh/chị đã được hút bao giờ chưa? ☐ Đã từng hút rồi ☐ Chưa hút bao giờ
Please indicate if septic tank has been desludged — Yes — No

32 Nếu bể tự hoại từng được hút, vui lòng ghi rõ năm gần nhất hút bể
If septic tank has been desludged, please list the latest desludging

Lý do hút bể ☐ Xí bị tắc ☐ Mùi hôi ☐ Sửa chữa nhà cửa
Reason for desludging — Clogging — Bad odour — House rebuild/repair

33 Vui lòng ghi các năm đã từng hút bể và nguyên nhân phải hút bể
Please list all desludging and reasons

Năm / Year — Lý do hút / Reason — ☐ Xí bị tắc / Clogging — ☐ Mùi hôi / Bad odour — ☐ Sửa chữa nhà cửa / House rebuild/repair

Năm / Year — Lý do hút / Reason — ☐ Xí bị tắc / Clogging — ☐ Mùi hôi / Bad odour — ☐ Sửa chữa nhà cửa / House rebuild/repair

Năm / Year — Lý do hút / Reason — ☐ Xí bị tắc / Clogging — ☐ Mùi hôi / Bad odour — ☐ Sửa chữa nhà cửa / House rebuild/repair

Năm / Year — Lý do hút / Reason — ☐ Xí bị tắc / Clogging — ☐ Mùi hôi / Bad odour — ☐ Sửa chữa nhà cửa / House rebuild/repair

34 Khi muốn hút bùn, gia đình liên hệ với dịch vụ bằng cách nào
How do you contact desluging service

☐ Quảng cáo / Commercial ☐ Thông tin từ hàng xóm/người dân địa phương / Neighbour/local people ☐ Khác (ghi rõ) / Other (indicate)

35 Anh/chị nghĩ sao về chi phí trả tiền hút bể phốt ☐ Cao (đắt) / Expensive ☐ Vừa phải / Acceptable ☐ Rẻ / Cheap

QUẢN LÝ PHÂN BÙN BỂ PHỐT
Septage management

36 Anh/chị có biết tác dụng của việc hút bể phốt định kỳ không ☐ Có / Yes ☐ Không / No
Do you know the effect of regular desludging?

37 Anh/chị có biết phân bùn sau khi hút được đổ đi đâu không, nếu có vui lòng ghi rõ
Do you know to which the septage goes to?

☐ Có (ghi rõ) / Yes ☐ Không / No

38 Nếu hút bể phốt được yêu cầu hút định kỳ, anh/chị có sẵn sàng tuân thủ không? Vì sao?
If regular desludging is required, are you willing to comply with? Why?

☐ Có (ghi rõ) / Yes

☐ Không (ghi rõ) / No

39 Nếu anh/chị lo lắng đến chi phí, vui lòng cho biết số tiền anh/chị có thể chi trả
If you concern about price, how much you can pay for that?

☐ < 1.000.000 đồng ☐ 1.500.000 - 2.000.000 đồng
☐ 1.000.000 - 1.500.000 đồng ☐ > 2.000.000 đồng

40 Theo anh/chị, hút bể định kỳ bao lâu thì có thể tuân thủ được?

☐ Mỗi năm 1 lần / Once every year ☐ 2 năm một lần / Once every 2 year ☐ 3 năm một lần / Once every 3 year ☐ 4 năm một lần / Once every 4 year ☐ 5 năm một lần / Once every 5 year

41 Anh/chị tán thành hay phản đối việc sử dụng phân hữu cơ (compost) làm từ phân bùn bể phốt? Tại sao?
Are you positive or negative to compost made from septage? Why?

☐ Có (ghi rõ) / Yes

☐ Không (ghi rõ) / No

42 Nếu tán thành, vui lòng liệt kê loại cây trồng có thể bón bằng phân compost làm từ phân bùn bể phốt
If you are positive, please mark the plants can be applied compost made from septage

☐ Rau / Vegetable ☐ Cây ăn quả / Fruit trees ☐ Cây cảnh / Bonsai ☐ Cây công nghiệp / Industrial trees

Xin chân thành cảm ơn sự hợp tác của quý anh/chị
Thank you very much for your cooperation

Gia đình có tham gia vào chương trình hút bể phốt miễn phí không? Will you join free-desludging strategy?	☐ Có Yes	☐ Không No
Khả năng lấy mẫu đầu ra của bể tự hoại Possibility to sample septic tank effluent	☐ Được Yes	☐ Không được No

Viết vài dòng mô tả về vị trí tiếp cận với bể tự hoại và đầu ra của nó để ghi nhớ
Note about possibility to access septic tank and its effluent

Appendix III (B)

Flow-rate measurement every 15 minutes at the outlet point of the drainage watershed at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi (00:00 January 8, 2014 – 24:00 January 9, 2014) (Chapter 5)

Time	Flow-rate at minute (m^3/h)			
	0'	15'	30'	45'
0-1 AM	0.5818	0.3848	0.3848	0.3202
1-2 AM	0.3202	0.2300	0.2300	0.1678
2-3 AM	0.1678	0.1160	0.1160	0.1160
3-4 AM	0.1160	0.1160	0.1160	0.1160
4-5 AM	0.1160	0.0732	0.1160	0.0732
5-6 AM	0.7320	0.7320	0.1160	0.1160
6-7 AM	0.3022	0.4782	0.7397	1.7805
7-8 AM	2.4808	2.4808	1.7805	1.7805
8-9 AM	1.7805	1.1514	1.7805	1.1514
9-10 AM	1.1514	1.4577	1.7805	1.1514
10-11 AM	1.1514	1.7805	1.4577	1.7805
11 AM-12 PM	1.7805	1.1514	1.1514	1.4577
12-1 PM	1.4577	1.4577	0.5818	0.5818
1-2 PM	0.5818	0.8631	0.8631	1.1514
2-3 PM	0.7397	0.4782	0.4782	0.4782
3-4 PM	0.7397	0.7397	0.7397	0.4782
4-5 PM	0.4782	0.4782	0.7397	0.7397
5-6 PM	0.7397	0.7397	1.1514	1.1514
6-7 PM	1.1514	1.4577	1.1514	1.1514
7-8 PM	1.7805	1.7805	1.7805	2.1228
8-9 PM	1.4577	1.1514	1.4577	1.4577
9-10 PM	1.4577	1.7805	1.7805	1.7805
10-11 PM	1.7805	1.7805	1.4577	1.4577
11 PM-12 AM	1.1514	0.7397	0.5818	0.4782
0-1 AM	0.3848	0.2300	0.2300	0.1678
1-2 AM	0.1678	0.1678	0.1160	0.1678
2-3 AM	0.1678	0.1678	0.1160	0.1160
3-4 AM	0.1160	0.1160	0.1160	0.1160
4-5 AM	0.0732	0.0732	0.0410	0.0732
5-6 AM	0.3848	0.3848	0.4782	0.7397
6-7 AM	1.1514	1.1514	0.8631	0.8631
7-8 AM	2.1228	2.1228	1.7805	1.7805
8-9 AM	1.7805	1.7805	1.7805	1.7805
9-10 AM	1.4577	1.4577	1.4577	1.4577
10-11 AM	0.8631	0.8631	1.7805	1.1514
11 AM-12 PM	1.1514	1.1514	1.1514	1.1514
12-1 PM	1.1514	1.1514	0.8631	0.8631
1-2 PM	0.8631	0.8631	0.5818	0.7397
2-3 PM	0.3848	0.3848	0.4782	0.2300
3-4 PM	0.4782	0.4782	0.8631	0.8631
4-5 PM	0.7397	0.7397	0.7397	0.7397
5-6 PM	0.7397	0.8631	1.1514	1.1514
6-7 PM	1.1514	1.1514	1.1514	1.7895
7-8 PM	1.7895	2.1228	2.1228	2.1228
8-9 PM	1.7805	1.7805	1.7805	1.4577
9-10 PM	1.4577	1.4577	1.4577	1.7805
10-11 PM	1.1514	1.1514	1.1514	1.1514
11 PM-12 AM	0.8631	0.8631	0.7397	0.5818

Appendix III (C)

Composition of septage samples by cylinder sampling and composite sampling (Chapter 5)

S1-1 and S3-1 are the samples obtained by cylinder sampling

S1-2 and S3-2 are the samples obtained by composite sampling

Sample ID	SS (mg/L)	VSS (mg/L)	BOD_5 (mg/L)	COD_{Cr} (mgL)	Cl^- (mg/L)	TKN (mg/L)	TP (mg/L)	Total coli form (CFU/100mL)	Alkalinity ($mgCaCO_3/L$)
S1-1	6,950	5,850	4,400	6,100	121	184	39	5.0E+06	1,250
S1-2	12,600	12,250	13,000	32,200	270	220	44	8.0E+06	725
S3-1	6,350	5,950	9,000	16,740	154	78	14	1.2E+07	2,025
S3-2	7,650	7,200	8,000	15,400	247	385	82	5.0E+07	1,970

Appendix III (D)

Survey results for 46 septic tanks at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi (Chapter 5)

No.	Family name	Loctaion	Family _size	Toilet _type	Last_desludging	ST_Length_ interview (m)	ST_Width_ interview (m)	ST_Height_ interview (m)	ST_Height_ measure (cm)	Scum_layer (cm)	Septage_depth (cm)	Solid_layer (cm)	Liquid_layer (cm)
1	Pham Thi Thuoc	Outside	8	1	2005/01/01	1.8	1.2	1.5	150		110	40	70
2	Nguyen Quang Huy	Outside	4	2	2000/01/01	2.1	1.1	1.3	135		105	10	95
3	Nguyen Duy Khu	Outside	4	1	2009/01/01	2	1.4	1.5	130		105	70	35
4	Nguyen Thi An	Inside	4	2	2010/01/01	2.2	1.5	1.75	110		92	10	82
5	Nguyen Van Ha	Inside	4	2	2003/01/01	2.2	1.6	1.35	110		97	10	87
6	Nguyen Thi Thoa	Inside	2	1	1997/01/01	1.8	1.6	1.25	160		135	25	110
7	Nguyen Tri Phuong	Inside	5	2	2002/01/01	1.8	1	1.4	110		95	20	75
8	Nguyen Duc Thang	Inside	4	3	1998/01/01	2.2	1.2	1.1	80		64	20	44
9	Tran Phuc Thong	Inside	2	1	2003/01/01	2.5	1.3	1.1	125		118	20	98
10	Tran Tien Dung	Inside	4	1	2007/01/01	1.6	1.2	1.45	100		85	10	75
11	Luu Van Thang	Inside	4	1	1998/01/01	1.4	1.1	1	130		115	20	95
12	Luu Ngoc Lai	Inside	4	1	2007/01/01	2.6	1.8	1.3	145		110	5	105
13	Nguyen Thanh Hai	Inside	4	2	2007/01/01	2.5	1.2	1.2	145		125	25	100
14	Tran Anh Phuoc	Inside	4	1	2007/01/01	2.2	1.2	1.35	120		110	10	100
15	Luu Ngoc Minh	Inside	4	2	2006/01/01	1.8	1.2	1.2	150		130	25	105
16	Nguyen Hai Long	Inside	3	2	1999/01/01	2	1.5	1.1	95		75	15	60
17	Pham Van Dong	Inside	5	2	2003/01/01	2	1.2	1.6	135		120	40	80
18	Phi Duc Son	Inside	5	1	2009/01/01	2	1.5	1.45	145	10	135	15	120
19	Pham Van Chung	Inside	4	2	2004/01/01	1.8	1.4	1.45	140		105	5	100
20	Phan Minh Hop	Outside	6	1	2003/01/01	1.5	1.2	0.95	125		90	10	80
21	Dinh Thi Ngo	Outside	5	3	2001/01/01	2	0.8	0.8	135		115	10	105
22	Dang Duc Thanh	Outside	15	1	2009/01/01	2.2	1.5	1.25	175	15	150	40	110
23	Pham Van Hoa	Outside	5	2	2002/01/01	1.8	1.5	1.3	140		130	25	105
24	Nguyen Minh Phuc	Outside	4	1	1998/01/01	1.5	1.2	1.5	130		110	10	100
25	Ho Thi Thanh Liem	Inside	4	1	2007/01/01	2.5	1.2	1.5	150		122	15	107

Note: Toilet type: 1-Normal cistern-flush, 2-Water-saving cistern-flush, 3-Pour-flush

Appendix III (D)

Survey results for 46 septic tanks at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi - continued (Chapter 5)

No.	Family name	Loctaion	Family_size	Toilet_type	Last_desludging	ST_Length_interview (m)	ST_Width_interview (m)	ST_Height_interview (m)	ST_Height_measure (cm)	Scum_layer (cm)	Septage_depth (cm)	Solid_layer (cm)	Liquid_layer (cm)
26	Trinh Minh Hanh	Inside	5	1	2001/01/01	2	1.4	1	150		135	25	110
27	Nguyen Van Son	Inside	4	1	2006/01/01	1.5	1.2	0.85	100		90	20	70
28	Tran Duy Cuong	Inside	4	1	2012/01/01	2	1.2	0.95	85		75	5	70
29	Nguyen Thi Thi	Outside	7	3	2001/01/01	2.2	1.2	1.35	95		80	15	65
30	Dinh Thi Nga	Outside	6	3	2009/01/01	2.4	1.2	1.35	135		115	5	110
31	Nguyen Van Hao	Outside	3	1	2004/01/01	2.3	1.2	1.2	130		110	10	100
32	Pham Ngoc Sinh	Outside	7	1	2002/01/01	1.8	1.2	1.3	120		100	15	85
33	Luong Ngoc Cuong	Inside	4	3	1999/01/01	1	0.7	2	70		65	15	50
34	Pham Minh Luong	Outside	5	3	2010/01/01	1	1.5	2	112		102	10	92
35	Dinh Van Thinh	Outside	5	1	2004/01/01	2	1.3	1.2	116		108	8	100
36	Ho Van Dung	Outside	5	1	2004/01/01	2	1.4	1.5	153		138	5	133
37	Phi Van Sau	Outside	5	1	2002/01/01	1.8	1.2	1.3	126		114	22	92
38	Phi Van Tam	Outside	7	2	2000/01/01	2.2	1.6	1.6	157		142	15	127
39	Phi Van Kinh	Outside	4	1	2005/01/01	2	1.6	1.5	145	10	124	17	107
40	Luong Duc Cuong	Outside	4	1	2002/01/01	1.6	1.2	1.5	135		123	13	110
41	Pham Anh Tu	Outside	5	1	2000/01/01	1.1	1.2	2.5	133		120	11	109
42	Nguyen Trí Tao	Outside	9	1	2005/01/01	1.8	1.3	1.5	152		144	21	123
43	Pham Van Quy	Outside	6	2	1997/01/01	1.8	1.2	1.5	112		101	24	77
44	Đinh Van Quyet	Outside	6	3	2011/01/01	1.1	1.2	2.5	132		120	20	100
45	Dinh Van Hai	Outside	5	3	2003/01/01	1.15	1	2	115	10	103	15	88
46	Pham Thi Thuy	Outside	5	1	2006/01/01	1.5	1.3	2.4	150		140	18	122

Note: Toilet type: 1-Normal cistern-flush, 2-Water-saving cistern-flush, 3-Pour-flush

Appendix III (E)

Septic tank effluent quality for 46 septic tanks at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi (Chapter 5)

No.	Family name	Loctaion	Sampling date	pH	EC (mS/cm)	Temp. (^oC)	SS (mg/L)	VSS (mg/L)	BOD_5 (mg/L)	COD_{Cr} (mgL)	Cl^- (mg/L)	TKN (mg/L)	TP (mg/L)	Total coli form (CFU/100mL)
1	Pham Thi Thuoc	Outside	2013/11/14	7.1	2.70	24.9	733	689	380	455	32	19.6	15.3	5.00E+06
2	Nguyen Quang Huy	Outside	2013/12/05	7.1	1.46	21.7	20	13	60	200	71	1.3	0.9	3.00E+05
3	Nguyen Duy Khu	Outside	2013/12/05	7.5	2.40	21.8	206	150	320	450	147	3.5	2.4	7.00E+06
4	Nguyen Thi An	Inside	2013/12/05	8.2	2.60	23.8	106	87	200	282	11	3.1	2.2	2.00E+05
5	Nguyen Van Ha	Inside	2013/12/05	7.3	2.30	22.3	28	28	160	273	128	4.2	2.7	1.00E+04
6	Nguyen Thi Thoa	Inside	2013/12/05	7.1	2.60	23.5	15	13	80	109	213	2.1	1.5	1.00E+05
7	Nguyen Tri Phuong	Inside	2013/12/05	7.8	2.10	22.5	69	68	180	264	9	3.9	2.6	1.00E+06
8	Nguyen Duc Thang	Inside	2013/12/06	6.9	1.78	21.9	172	157	240	510	43	2.9	2.1	1.00E+07
9	Tran Phuc Thong	Inside	2013/12/06	7.3	2.20	24.3	72	67	120	196	120	3.1	2.0	7.00E+06
10	Tran Tien Dung	Inside	2013/12/06	7.3	1.85	22.7	24	22	200	296	61	2.3	1.6	7.00E+05
11	Luu Van Thang	Inside	2013/12/06	7.3	2.60	22.5	18	16	80	214	145	7.7	6.0	6.00E+05
12	Luu Ngoc Lai	Inside	2013/12/06	8	1.98	23.6	38	22	160	209	101	2.0	1.3	4.00E+05
13	Nguyen Thanh Hai	Inside	2013/12/06	7.3	1.95	23.5	71	70	300	405	74	7.4	5.1	6.00E+06
14	Tran Anh Phuoc	Inside	2013/12/06	7.3	2.00	22.5	12	12	100	155	81	2.1	1.2	3.00E+04
15	Luu Ngoc Minh	Inside	2013/12/06	8	2.50	23.0	46	46	220	300	16	4.2	2.9	3.00E+04
16	Nguyen Hai Long	Inside	2013/12/07	8	3.20	22.8	83	47	160	328	202	5.4	3.8	8.00E+04
17	Pham Van Dong	Inside	2013/12/07	7.1	3.00	22.3	58	56	120	237	36	6.3	4.2	7.00E+04
18	Phi Duc Son	Inside	2013/12/07	7.6	3.10	22.8	38	16	80	273	184	8.9	6.4	5.00E+05
19	Pham Van Chung	Inside	2013/12/07	7.6	2.70	23.0	88	86	140	232	125	8.1	5.8	5.00E+05
20	Phan Minh Hop	Outside	2013/12/07	7.5	2.20	22.7	57	55	120	214	10	3.0	2.2	7.00E+05
21	Dinh Thi Ngo	Outside	2013/12/07	6.9	1.90	22.2	20	20	80	91	85	2.1	1.3	4.00E+05
22	Dang Duc Thanh	Outside	2013/12/22	7.5	2.80	18.2	79	70	360	645	67	29.4	6.2	1.00E+07
23	Pham Van Hoa	Outside	2013/12/25	7.7	1.23		45	40	180	369	40	25.2	5.2	5.00E+06
24	Nguyen Minh Phuc	Outside	2014/01/16	6.86	3.29	19.3	32	30	440	646	155	30.1	6.5	9.00E+05
25	Ho Thi Thanh Liem	Inside	2014/01/16	7.86	2.47	20.2	1876	1569	1800	3095	162	36.4	7.6	4.00E+05

Appendix III (E)

Septic tank effluent quality for 46 septic tanks at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi - continued

(Chapter 5)

No.	Family name	Loctaion	Sampling date	pH	EC (mS/cm)	Temp. (^oC)	SS (mg/L)	VSS (mg/L)	BOD_5 (mg/L)	COD_{Cr} (mgL)	Cl^- (mg/L)	TKN (mg/L)	TP (mg/L)	Total coli form (CFU/100mL)
26	Trinh Minh Hanh	Inside	2014/01/16	7.78	2.73	18.7	34	24	240	446	189	25.9	5.6	1.00E+05
27	Nguyen Van Son	Inside	2014/01/16	7.17	2.62	19.2	24	14	160	332	135	28.0	6.0	2.00E+05
28	Tran Duy Cuong	Inside	2014/01/17	8.3	2.50	18.5	190	160	400	628	198	7.0	32.9	1.00E+07
29	Nguyen Thi Thi	Outside	2014/01/18	8.2	1.88	19.4	42	38	200	300	79	18.2	3.9	3.00E+07
30	Dinh Thi Nga	Outside	2014/01/18	7.3	2.50	19.3	28	16	140	228	86	20.3	4.4	1.00E+05
31	Nguyen Van Hao	Outside	2014/01/18	7.5	3.40	19.0	44	42	320	532	138	22.4	4.8	8.00E+06
32	Pham Ngoc Sinh	Outside	2014/01/18	8	5.40	19.5	162	144	1800	3525	47	32.2	6.9	8.00E+06
33	Luong Ngoc Cuong	Inside	2014/03/04	7.1	3.00	22.1	720	540	920	1775	136	8.1	5.6	3.50E+08
34	Pham Minh Luong	Outside	2014/03/04	7.41	0.96	21.2	189	180	200	276	355	68.6	14.5	1.E+06
35	Dinh Van Thinh	Outside	2014/03/04	7.88	1.81	20.6	242	230	350	480	610	81.2	17.2	2.E+05
36	Ho Van Dung	Outside	2014/03/04	7.94	1.19	21.4	303	275	320	422	213	42.0	8.7	2.E+06
37	Phi Van Sau	Outside	2014/03/05	7.11	1.17	19.7	70	66	380	407	284	21.7	4.5	3.E+06
38	Phi Van Tam	Outside	2014/03/05	7.35	1.64	20.0	189	178	410	664	269	202.3	42.2	6.E+05
39	Phi Van Kinh	Outside	2014/03/05	7.74	1.73	19.8	364	300	400	514	269	200.2	42.0	2.E+06
40	Luong Duc Cuong	Outside	2014/03/11	7.82	1.48	19.1	492	480	760	995	30	348.6	72.4	4.E+06
41	Pham Anh Tu	Outside	2014/03/11	8.86	4.00	19.3	228	214	320	495	312	57.4	12.0	9.E+05
42	Nguyen Trí Tao	Outside	2014/03/11	7.7	1.48	19.5	205	185	360	732	44	186.2	39.0	2.E+06
43	Pham Van Quy	Outside	2014/03/12	7.64	1.27	19.5	216	187	420	519	426	68.6	14.5	1.E+06
44	Đinh Van Quyet	Outside	2014/03/12	7.82	1.67	18.9	289	259	450	501	540	691.6	145.5	3.E+05
45	Dinh Van Hai	Outside	2014/03/12	7.46	1.77	20.3	528	192	580	747	582	6.3	1.4	3.E+06
46	Pham Thi Thuy	Outside	2014/03/12	7.47	1.78	19.8	2630	2030	2350	2835	625	183.4	37.8	5.E+06

Appendix III (F)

Septage composition for 46 septic tanks at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi (Chapter 5)

No.	Family name	Loctaion	Sampling date	pH	EC (mS/cm)	Temp. (^{o}C)	SV30 (%)	SS (mg/L)	VSS (mg/L)	BOD_5 (mg/L)	COD_{Cr} (mgL)	Cl^- (mg/L)	TKN (mg/L)	TP (mg/L)	Total coli form (CFU/100mL)	Alkalinity ($mgCaCO_3/L$)
1	Pham Thi Thuoc	Outside	2013/11/14	7.1	2.7	24.9	100	40,160	40,016	28,000	37,840	504.0	73.1	46	5.0E+06	1,015
2	Nguyen Quang Huy	Outside	2013/12/25	7	1.75	17.8	29	3,600	3,300	3,200	5,380	112.0	22.9	119	7.0E+06	1,175
3	Nguyen Duy Khu	Outside	2013/12/22	7.9	3.2	18.1	70	9,150	8,450	11,000	21,700	120.4	25.6	189	7.0E+06	2,100
4	Nguyen Thi An	Inside	2014/01/14	8.4	3.5	18.5	14	6,100	5,250	5,000	7,740	244.3	52.0	202	3.0E+06	1,740
5	Nguyen Van Ha	Inside	2014/01/13	7.79	2.6	17.7	89	22,250	20,750	14,000	19,640	84.0	17.6	256	1.0E+08	2,160
6	Nguyen Thi Thoa	Inside	2014/01/14	7.2	3.1	17.9	32	6,166	5,500	4,000	7,920	86.1	18.4	246	8.0E+06	1,460
7	Nguyen Tri Phuong	Inside	2014/01/13	7.69	3.1	17.5	94	36,200	32,800	22,000	29,120	224.0	44.8	175	4.0E+06	2,300
8	Nguyen Duc Thang	Inside	2014/01/15	7.7	2.8	16.3	100	5,000	4,500	23,500	44,800	1445.5	307.6	175	1.0E+07	2,840
9	Tran Phuc Thong	Inside	2014/01/15	7.4	3	17.7	95	10,555	9,305	29,000	42,750	201.6	42.9	202	6.0E+05	2,060
10	Tran Tien Dung	Inside	2014/01/13	7.43	2.6	17.3	63	12,800	11,600	18,000	26,560	213.5	44.4	108	1.0E+08	1,660
11	Luu Van Thang	Inside	2014/01/13	7.59	3.2	17.4	85	31,000	29,000	30,000	78,700	343.7	73.1	236	9.0E+07	2,980
12	Luu Ngoc Lai	Inside	2014/01/14	8.2	2.7	18.6	9	5,200	4,650	3,500	4,480	117.6	25.6	131	3.0E+06	1,460
13	Nguyen Thanh Hai	Inside	2013/12/22	7.3	2.2	17.3	97	12,600	12,250	13,000	32,200	219.8	44.2	270	8.0E+06	1,250
14	Tran Anh Phuoc	Inside	2014/01/13	7.83	1.89	17.5	36	13,000	11,300	12,000	15,840	112.0	23.3	202	4.0E+07	1,543
15	Luu Ngoc Minh	Inside	2013/12/22	7.5	3.8	17.8	55	7,650	7,200	8,000	15,400	385.0	82.0	247	5.0E+07	1,970
16	Nguyen Hai Long	Inside	2014/01/14	8.32	4.7	18.5	24	6,900	5,200	5,000	7,050	311.5	59.9	327	2.0E+08	2,200
17	Pham Van Dong	Inside	2014/01/13	7.81	2.7	17.9	37	8,300	7,700	8,000	13,200	84.7	17.2	229	8.0E+06	2,160
18	Phi Duc Son	Inside	2014/01/14	8.3	3.8	19.1	8	4,350	3,750	2,000	2,550	730.8	155.5	194	1.0E+07	1,700
19	Pham Van Chung	Inside	2014/01/13	7.71	3.8	17.6	51	29,000	27,000	8,000	12,360	340.2	70.9	216	4.0E+07	1,980
20	Phan Minh Hop	Outside	2013/12/25	7.8	1.82	17.9	59	6,600	4,733	4,400	7,200	81.2	16.5	3	3.0E+05	130
21	Dinh Thi Ngo	Outside	2014/01/18	7.6	2.6	18.7	95	9,600	8,000	21,000	30,250	652.4	138.8	310	9.0E+06	2,100
22	Dang Duc Thanh	Outside	2013/12/22	7.1	2.8	17.4	77	14,300	14,000	14,000	23,640	456.4	94.6	378	6.0E+07	1,725
23	Pham Van Hoa	Outside	2013/12/25	7.5	1.23	17.9	32	8,160	7,920	7,000	13,800	84.0	17.5	209	6.0E+06	1,500
24	Nguyen Minh Phuc	Outside	2014/01/17	7.3	3.6	18.4	66	12,500	8,875	11,000	14,020	80.4	378.0	216	2.0E+07	1,960
25	Ho Thi Thanh Liem	Inside	2014/01/17	8	2.4	20.2	37	10,300	6,700	6,000	10,920	150.2	707.0	229	6.0E+06	1,350

Appendix III (F)

Septage composition for 46 septic tanks at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi – continued

(Chapter 5)

No.	Family name	Loctaion	Sampling date	pH	EC (mS/cm)	Temp. (^oC)	SV30 (%)	SS (mg/L)	VSS (mg/L)	BOD_5 (mg/L)	COD_{Cr} (mgL)	Cl^- (mg/L)	TKN (mg/L)	TP (mg/L)	Total coli form (CFU/100mL)	Alkalinity ($mgCaCO_3/L$)
26	Trinh Minh Hanh	Inside	2014/01/17	7.7	2.8	18.8	100	22,000	17,500	27,000	43,250	240.9	1132.6	243	4.0E+07	2,560
27	Nguyen Van Son	Inside	2014/01/17	7.9	2.6	18.5	100	14,857	11,571	19,000	21,375	217.8	1024.1	148	5.0E+06	1,800
28	Tran Duy Cuong	Inside	2014/01/17	8.3	2.4	18.4	100	36,333	29,666	450	919	256.1	1204.0	297	1.0E+08	3,100
29	Nguyen Thi Thi	Outside	2014/01/18	8	2.1	18.4	65	16,850	12,700	16,000	21,950	606.2	129.0	229	8.0E+06	2,240
30	Dinh Thi Nga	Outside	2014/01/18	7.1	2.2	19.3	8	3,500	1,150	1,500	2,550	214.9	45.7	96	2.0E+05	1,120
31	Nguyen Van Hao	Outside	2014/01/18	7.7	3	19.4	68	9,600	6,800	12,000	29,800	910.0	193.7	162	2.0E+07	1,860
32	Pham Ngoc Sinh	Outside	2014/01/18	7.5	5	21.1	65	11,000	8,000	19,000	24,800	809.2	172.2	121	9.0E+06	2,930
33	Luong Ngoc Cuong	Inside	2014/03/04	7.52	4	20.5	98	46,780	45,650	21,000	28,700	380.7	59.2	284	5.8E+08	2,900
34	Pham Minh Luong	Outside	2014/03/04	7.66	1.89	20.6	73	7,100	7,000	10,000	11,880	165.9	34.7	270	2.8E+08	1,640
35	Dinh Van Thinh	Outside	2014/03/04	7.41	1.8	20.9	99	29,750	28,920	22,000	27,500	210.0	44.7	426	9.0E+07	3,100
36	Ho Van Dung	Outside	2014/03/04	6.87	1.36	20.9	40	4,950	4,810	9,000	11,250	139.3	28.5	298	3.0E+08	1,340
37	Phi Van Sau	Outside	2014/03/05	7.15	0.994	19.4	99	10,420	10,120	20,800	25,600	249.2	52.4	412	2.8E+07	3,060
38	Phi Van Tam	Outside	2014/03/05	7.25	1.58	20.2	2	523	503	8,000	9,500	68.6	14.5	440	2.4E+06	1,280
39	Phi Van Kinh	Outside	2014/03/05	7.18	1.78	19.7	40	5,530	5,470	7,400	9,120	166.6	35.3	256	5.4E+07	2,570
40	Luong Duc Cuong	Outside	2014/03/11	7.33	1.94	19.5	90	20,971	20,689	21,000	25,000	63.7	13.3	340	6.0E+07	3,060
41	Pham Anh Tu	Outside	2014/03/11	7.96	4	19.9	8	1,475	1,386	1,500	2,815	60.2	12.6	312	1.3E+07	1,960
42	Nguyen Trí Tao	Outside	2014/03/11	7.28	1.58	19.4	8	1,150	1,105	1,500	3,820	233.1	49.7	284	8.3E+06	1,560
43	Pham Van Quy	Outside	2014/03/12	7.68	1.32	19.9	95	8,841	8,763	18,000	20,850	165.2	34.9	398	3.6E+06	1,900
44	Đinh Van Quyet	Outside	2014/03/12	7.23	1.76	19.4	98	40,033	39,542	37,500	44,100	393.4	83.1	326	2.0E+07	3,000
45	Dinh Van Hai	Outside	2014/03/12	7.43	1.86	19.9	100	29,309	29,105	26,000	36,150	413.0	85.7	369	1.1E+07	3,000
46	Pham Thi Thuy	Outside	2014/03/12	7.35	1.92	20.3	10	11,208	11,157	1,800	7,370	340.2	70.0	156	3.4E+06	2,250

Appendix III (G)

Fresh septage composition for 8 septic tanks at Lai Xa hamlet, Kim Chung commune, Hoai Duc district, Hanoi

(Chapter 5)

No.	Family name	Loctaion	Sampling date	pH	EC (mS/cm)	Temp. (^oC)	SS (mg/L)	VSS (mg/L)	BOD_5 (mg/L)	COD_{Cr} (mgL)	Cl^- (mg/L)	TKN (mg/L)	TP (mg/L)	Total coli form (CFU/100mL)
1	Nguyen Van Ha	Inside	2014/01/15	8.06	1.97	17.5	6,666	5,333	23,000	36,400	148	451	92	6.0E+07
2	Nguyen Thi Thoa	Inside	2014/01/16	7.29	2.9	18.8	36,333	27,333	32,000	35,840	283	226	48	5.0E+07
3	Nguyen Tri Phuong	Inside	2014/01/15	8.12	2.2	17.3	17,500	15,750	19,000	27,750	269	385	74	9.0E+07
4	Tran Tien Dung	Inside	2014/01/16	8.12	2.2	20	9,700	8,300	14,500	18,200	191	30	6	1.0E+08
5	Luu Van Thang	Inside	2014/01/15	8.12	2.2	18.2	21,666	17,166	23,000	31,320	310	616	128	7.0E+07
6	Tran Anh Phuoc	Inside	2014/01/16	8.17	2.5	18.2	13,000	10,600	24,500	31,320	202	514	109	1.0E+07
7	Pham Van Dong	Inside	2014/01/16	7.53	4.3	16.5	20,000	18,000	29,000	36,400	263	458	97	2.0E+07
8	Pham Van Chung	Inside	2014/01/15	8.55	2.7	18.2	11,500	8,750	14,500	20,040	256	465	99	4.0E+07

Appendix IV (A)

Septic tank survey in urban areas of Danang (*n*=36) (Chapter 6)

No.	Sampling date	Name	Toilet type	ST_construct_year	ST_shape	ST_no.of chamber	ST_size (m^3)	ST_effliuent_to	ST_access port
1	2012/03/09	Lê Thị Kinh	Cistern-flush	1997/01/01	Rectangular	3	2.88	Soak pit	Cement-fixed
2	2012/03/09	Đoàn Thị Xoa	Cistern-flush	1993/01/01	Rectangular	3	7.168	Soak pit	No port
3	2012/03/10	Lê Thuận	Pour-flush	1992/01/01	Rectangular	3	2.944	Soak pit	No port
4	2012/03/11	Nguyễn Kháng	Pour-flush	2000/01/01	Rectangular	3	3.72	Soak pit	No port
5	2012/03/11	Nguyễn Chở	Pour-flush	1995/01/01	Rectangular	2	2.88	Drainage	No port
6	2012/03/11	Nguyễn Văn Tư	Pour-flush	2007/01/01	Rectangular	2	1.2	Soak pit	Openable
7	2012/03/12	Nguyễn Thị Thu Huyền	Cistern-flush	2006/01/01	Rectangular	3	3.9	Soak pit	No port
8	2012/03/12	Nguyễn Thị Thu Hồng	Pour-flush	1991/01/01	Rectangular	3	3.888	Soak pit	Openable
9	2012/03/12	Nguyễn Phong	Pour-flush	1997/01/01	Rectangular	3	5.04	Soak pit	No port
10	2012/03/12	Nguyễn Sĩ Hiếu	Cistern-flush	1999/01/01	Rectangular	3	7.2	Soak pit	No port
11	2012/03/14	Nguyễn Văn Thu	Cistern-flush	1980/01/01	Rectangular	3	3	Soak pit	No port
12	2012/03/14	Nguyễn Thị Thanh	Cistern-flush	N/A	Rectangular	3	N/A	Drainage	No port
13	2012/03/14	Đặng Quốc Hùng	Cistern-flush	2002/01/01	Cylindrical	3	N/A	Soak pit	Cement-fixed
14	2012/03/14	Phạm Thị Kiên	Cistern-flush	2002/01/01	Cylindrical	3	N/A	Soak pit	No port
15	2012/03/14	Vũ Văn Long	Cistern-flush	2010/01/01	Rectangular	3	3.528	Soak pit	No port
16	2012/03/15	Nguyễn Thị Hồng Ánh	Cistern-flush	2000/01/01	Rectangular	3	3.15	Soak pit	Cement-fixed
17	2012/03/15	Đặng Văn Phú	Pour-flush	2003/01/01	Rectangular	3	3.6	Soak pit	No port
18	2012/03/16	Đoàn Huy Hợp	Pour-flush	1998/01/01	Rectangular	3	2.8	Soak pit	No port
19	2012/03/16	Vũ Xuân Trường	Cistern-flush	N/A	Rectangular	3	N/A	Soak pit	No port
20	2012/03/16	Đinh Văn Khê	Pour-flush	1972/01/01	Rectangular	3	3.468	Soak pit	No port
21	2012/03/17	Lê Hồng Thúy	Cistern-flush	2003/01/01	Rectangular	3	2.7	Drainage	No port
22	2012/03/17	Nguyễn Văn Hòa	Cistern-flush	2000/01/01	Rectangular	3	6.6	Soak pit	No port
23	2012/03/17	Lê Viết Vĩnh	Pour-flush	1975/01/01	Cylindrical	3	1.99168	Soak pit	No port
24	2012/03/19	Châu Việt Hùng	Cistern-flush	2006/01/01	Rectangular	3	3.672	Soak pit	Openable
25	2012/03/19	Nguyễn Mạnh Hùng	Pour-flush	1998/01/01	Rectangular	3	4.14	Soak pit	No port
26	2012/03/19	Nguyễn Phước Dũng	Pour-flush	2002/01/01	Rectangular	3	3.24	Soak pit	No port
27	2012/03/20	Võ Quang Liêm	Pour-flush	2006/01/01	Rectangular	3	4.32	Soak pit	No port
28	2012/03/20	Phạm Ngọc Dung	Cistern-flush	N/A	Rectangular	3	3.6	Soak pit	No port
29	2012/03/21	Lê Cao Đạt	Pour-flush	2003/01/01	Rectangular	3	4.42	Soak pit	No port
30	2012/03/22	Ngô Văn Đạt	Cistern-flush	1997/01/01	Rectangular	3	3.56	Soak pit	No port
31	2012/03/22	Võ Mạnh	Pour-flush	2004/01/01	Cylindrical	3	1.60768	Soak pit	No port
32	2012/03/23	Nguyễn Thị Vân	Cistern-flush	N/A	Rectangular	3	N/A	Soak pit	No port
33	2012/03/23	Đinh Thị Tám	Pour-flush	1992/01/01	Rectangular	3	3.16	Soak pit	No port
34	2012/03/23	Nguyễn Lê Vĩnh	Pour-flush	N/A	Rectangular	2	2.048	Soak pit	No port
35	2012/03/24	Trương Tấn Việt	Cistern-flush	2007/01/01	Rectangular	3	1.92	Soak pit	Openable
36	2012/03/24	Trần Việt Hùng	Pour-flush	1998/01/01	Rectangular	3	4.87356	Soak pit	No port

Note: N/A is “not available”

Appendix IV (B)

Septage composition of septic tank connected to cistern-flush and pour-flush toilet (*n*=20) (Chapter 6)

Composition of septage in septic tanks connected to cistern-flush toilets

No.	Name	ST size (m^3)	Cl^-_1 (mg/L)	pH	Alkalinity ($mgCaCO_3/L$)	SS (mg/L)	VSS (mg/L)	TDS (mg/L)	BOD_5 (mg/L)	COD_{Mn} (mg/L)	COD_{Cr} (mg/L)	$N\text{-}NH_4$ (mg/L)	TKN (mg/L)	$P\text{-}PO_4$ (mg/L)	T-P (mg/L)	Cl^-_2 (mg/L)	Coliform (MPN/100mL)	SV30 (%)
1	Lê Thị Kinh	2.88	501.6	7.5	2,500	68,500	57,400	8,050	14,700	28,600	64,400	570	4,800	141	1,751	506	1.6.E+06	100
2	Đoàn Thị Xoa	7.17	422.5	7.8	2,300	61,070	49,500	8,700	12,600	24,800	48,700	508	4,200	191	1,681	441	9.2.E+06	100
3	Nguyễn Thị Thu Huyền	3.90	108.5	8	2,300	16,300	12,800	5,400	8,900	15,800	32,000	318	1,820	140	214	285	5.1.E+05	45
4	Nguyễn Sĩ Hiếu	7.20	402.6	7.6	2,250	46,800	40,300	6,070	19,500	24,600	58,300	603	2,860	169	1,517	112	9.0.E+05	95
5	Nguyễn Văn Thu	3.00	413.9	7.3	1,830	1,750	1,460	3,864	842	1,280	3,530	69	521	70	190	306	7.2.E+04	12
6	Vũ Văn Long	3.53	198.8	7.6	1,450	3,210	2,680	2,660	4,520	6,280	9,860	103	864	55	120	206	2.2.E+05	30
7	Nguyễn Thị Hồng Ánh	3.15	301.7	8	2,380	2,860	2,245	2,830	643	948	2,550	88	408	53	99	319	3.6.E+06	4
8	Châu Việt Hùng	3.67	435.8	7.7	1,870	18,750	16,300	5,600	11,500	17,300	33,700	258	986	118	461	429	3.2.E+06	67
9	Ngô Văn Đạt	3.56	303.7	7.3	1,985	8,770	7,520	5,780	389	5,830	8,160	90	741	73	1,207	439	7.2.E+04	78
10	Trương Tấn Việt	1.92	282.8	8.1	2,760	48,900	36,840	6,200	18,652	30,700	53,500	512	3,820	186	2,028	408	9.2.E+06	100

Composition of septage in septic tanks connected to pour-flush toilets

No.	Name	ST size (m^3)	Cl^-_1 (mg/L)	pH	Alkalinity ($mgCaCO_3/L$)	SS (mg/L)	VSS (mg/L)	TDS (mg/L)	BOD_5 (mg/L)	COD_{Mn} (mg/L)	COD_{Cr} (mg/L)	$N\text{-}NH_4$ (mg/L)	TKN (mg/L)	$P\text{-}PO_4$ (mg/L)	T-P (mg/L)	Cl^-_2 (mg/L)	Coliform (MPN/100mL)	SV30 (%)
1	Lê Thuận	2.94	425.5	7.4	2,150	64,700	52,800	7,700	20,300	35,300	62,800	606	5,180	154	1,542	169	2.2.E+06	100
2	Nguyễn Kháng	3.72	165.3	7.3	1,300	18,500	11,600	4,500	8,700	12,600	28,000	207	1,680	120	485	186	3.6.E+05	40
3	Nguyễn Thị Thu Hồng	3.89	454.3	8.1	2,450	58,800	51,100	8,260	12,700	31,100	57,300	488	4,620	162	1,548	268	3.6.E+06	100
4	Nguyễn Phong	5.04	502.5	7.8	2,600	55,800	46,700	7,690	24,800	30,500	61,800	625	3,880	147	1,428	507	5.1.E+06	100
5	Đặng Văn Phú	3.60	324.5	7.8	1,980	24,200	18,600	7,400	17,300	24,700	41,700	360	2,040	128	595	336	5.1.E+05	63
6	Đoàn Huy Hợp	2.80	253.8	8.2	3,280	73,200	64,900	8,800	22,600	37,502	60,800	527	3,680	159	1,207	258	1.6.E+06	100
7	Nguyễn Phước Dũng	3.24	183.3	7.9	2,280	38,600	31,600	5,800	15,600	26,400	29,700	306	1,960	123	686	438	5.1.E+05	78
8	Lê Cao Đạt	4.42	262.5	7.5	1,680	25,500	20,400	6,400	20,570	28,800	54,800	464	3,087	166	1,213	461	2.2.E+04	89
9	Đinh Thị Tám	3.16	405.6	7.9	2,500	38,600	27,300	6,380	1,208	19,800	45,800	367	4,081	141	1,825	409	5.1.E+06	100
10	Trần Việt Hùng	4.87	276.6	8	1,860	53,800	46,300	7,830	17,556	25,800	47,200	615	3,690	175	1,250	283	2.2.E+04	96

Note: Cl^-_1 and Cl^-_2 are Cl^- concentrations of the sample at home (right after septic tank had been opened) and composite sample at discharging place, respectively.

Appendix V

Septic tank management and septage to compost (*n*=236) (Chapter 7)

U_HAN: Urban Hanoi, S_HAN: Sub-urban Hanoi, U_DAN: Urban Danang

Y: Yes, N: No, T: Treatment plant, D.K.: Don't know, A.H.: Agree if hygienically treated, H: Hygiene

Respondent No.	Location	Role of desludging	Septage to where	Septage to compost	Concern
1	U_HAN	N	N	Y	N
2	U_HAN	N	N	N	H
3	U_HAN	N	T	Y	N
4	U_HAN	N	N	Y	N
5	U_HAN	N	N	N	N
6	U_HAN	N	N	Y	N
7	U_HAN	N	T	Y	N
8	U_HAN	N	N	Y	N
9	U_HAN	N	N	Y	N
10	U_HAN	N	N	Y	N
11	U_HAN	N	N	N	H
12	U_HAN	N	N	Y	N
13	U_HAN	N	N	Y	N
14	U_HAN	N	N	Y	N
15	U_HAN	N	T	Y	N
16	U_HAN	N	N	N	N
17	U_HAN	N	N	Y	N
18	U_HAN	N	N	Y	N
19	U_HAN	N	N	Y	N
20	U_HAN	N	N	Y	N
21	U_HAN	N	N	D.K.	N
22	U_HAN	N	N	Y	N
23	U_HAN	Y	T	Y	N
24	U_HAN	N	N	Y	N
25	U_HAN	N	N	Y	N
26	U_HAN	N	N	Y	N
27	U_HAN	N	T	Y	N
28	U_HAN	N	N	Y	N
29	U_HAN	N	N	Y	N
30	U_HAN	N	N	A.H.	H
31	U_HAN	N	T	Y	N
32	U_HAN	N	N	Y	N
33	U_HAN	N	N	Y	N
34	U_HAN	N	N	Y	N
35	U_HAN	N	N	Y	N
36	U_HAN	N	N	Y	N
37	U_HAN	Y	T	Y	N
38	U_HAN	N	N	Y	N
39	U_HAN	N	N	Y	H
40	U_HAN	N	N	Y	N

Respondent No.	Location	Role of desludging	Septage to where	Septage to compost	Concern
41	U_HAN	N	N	Y	N
42	U_HAN	N	T	Y	N
43	U_HAN	N	N	Y	N
44	U_HAN	N	N	Y	N
45	U_HAN	N	N	Y	N
46	U_HAN	N	N	Y	N
47	U_HAN	N	T	N	H
48	U_HAN	N	N	Y	N
49	U_HAN	N	T	Y	N
50	U_HAN	N	N	Y	N
51	U_HAN	N	N	Y	N
52	U_HAN	N	N	Y	N
53	U_HAN	N	T	Y	N
54	U_HAN	N	N	Y	N
55	U_HAN	N	N	Y	N
56	U_HAN	N	N	Y	N
57	U_HAN	N	N	Y	N
58	U_HAN	N	N	N	H
59	U_HAN	N	N	Y	N
60	U_HAN	N	N	Y	N
61	U_HAN	N	N	Y	N
62	U_HAN	N	N	Y	N
63	U_HAN	N	N	Y	N
64	U_HAN	N	N	Y	N
65	U_HAN	N	N	Y	N
66	U_HAN	N	N	Y	N
67	U_HAN	N	N	A.H.	H
68	U_HAN	N	N	Y	N
69	U_HAN	N	N	Y	N
70	U_HAN	N	N	A.H.	H
71	U_HAN	N	N	Y	N
72	U_HAN	N	N	Y	N
73	U_HAN	N	N	Y	N
74	U_HAN	N	N	Y	N
75	U_HAN	N	N	Y	N
76	U_HAN	N	N	Y	N
77	U_HAN	N	N	Y	N
78	U_HAN	N	N	A.H.	H
79	U_HAN	N	N	N	N
80	U_HAN	N	N	Y	N

Respondent No.	Location	Role of desludging	Septage to where	Septage to compost	Concern
81	U_HAN	N	N	Y	N
82	U_HAN	N	N	Y	N
83	U_HAN	N	N	Y	N
84	U_HAN	N	N	N	N
85	U_HAN	N	N	Y	H
86	U_HAN	N	N	Y	N
87	U_HAN	N	N	Y	N
88	U_HAN	N	N	Y	N
89	U_HAN	N	N	A.H.	H
90	U_HAN	N	N	Y	N
91	U_HAN	N	N	Y	N
92	U_HAN	N	N	Y	N
93	U_HAN	N	T	Y	N
94	U_HAN	N	N	Y	N
95	U_HAN	N	N	Y	N
96	U_HAN	N	N	N	H
97	U_HAN	N	N	Y	N
98	U_HAN	N	N	Y	N
99	U_HAN	N	N	Y	N
100	U_HAN	N	N	Y	N
101	S_HAN	N	N	Y	N
102	S_HAN	N	N	Y	N
103	S_HAN	N	N	Y	N
104	S_HAN	N	N	N	H
105	S_HAN	Y	T	Y	N
106	S_HAN	N	N	Y	N
107	S_HAN	Y	T	Y	N
108	S_HAN	N	N	Y	N
109	S_HAN	N	N	Y	N
110	S_HAN	N	N	Y	N
111	S_HAN	N	N	Y	N
112	S_HAN	N	N	Y	N
113	S_HAN	N	N	Y	N
114	S_HAN	N	N	D.K.	N
115	S_HAN	Y	T	Y	N
116	S_HAN	Y	T	Y	N
117	S_HAN	N	N	Y	N
118	S_HAN	N	N	Y	N
119	S_HAN	N	N	Y	N
120	S_HAN	N	N	Y	N

Respondent No.	Location	Role of desludging	Septage to where	Septage to compost	Concern
121	S_HAN	N	N	Y	N
122	S_HAN	N	N	N	H
123	S_HAN	N	N	Y	N
124	S_HAN	N	N	Y	N
125	S_HAN	N	N	Y	N
126	S_HAN	Y	T	N	N
127	S_HAN	N	N	Y	N
128	S_HAN	N	N	Y	N
129	S_HAN	N	N	Y	N
130	S_HAN	N	N	A.H.	N
131	S_HAN	N	N	Y	N
132	S_HAN	N	N	Y	N
133	S_HAN	N	N	Y	N
134	S_HAN	N	N	Y	N
135	S_HAN	Y	T	Y	N
136	S_HAN	N	N	Y	N
137	S_HAN	N	N	Y	N
138	S_HAN	N	N	Y	N
139	S_HAN	N	N	Y	N
140	S_HAN	Y	T	Y	N
141	S_HAN	N	N	Y	N
142	S_HAN	N	N	Y	N
143	S_HAN	N	N	Y	N
144	S_HAN	N	N	Y	N
145	S_HAN	N	N	Y	N
146	S_HAN	Y	N	Y	N
147	S_HAN	N	N	Y	N
148	S_HAN	N	N	Y	N
149	S_HAN	N	N	Y	N
150	S_HAN	N	N	Y	N
151	S_HAN	N	N	Y	N
152	S_HAN	N	N	Y	N
153	S_HAN	N	T	Y	N
154	S_HAN	Y	N	Y	N
155	S_HAN	N	N	Y	N
156	S_HAN	N	N	Y	N
157	S_HAN	N	N	Y	N
158	S_HAN	N	N	Y	N
159	S_HAN	N	N	Y	N
160	S_HAN	N	N	Y	N

Respondent No.	Location	Role of desludging	Septage to where	Septage to compost	Concern
161	S_HAN	N	N	Y	N
162	S_HAN	N	N	Y	N
163	S_HAN	N	N	Y	N
164	S_HAN	N	N	Y	N
165	S_HAN	N	N	Y	N
166	S_HAN	N	N	Y	N
167	S_HAN	N	N	Y	N
168	S_HAN	N	N	A.H.	N
169	S_HAN	N	N	Y	N
170	S_HAN	N	T	Y	N
171	S_HAN	N	N	Y	N
172	S_HAN	N	N	N	H
173	S_HAN	N	N	Y	N
174	S_HAN	N	N	Y	N
175	S_HAN	N	N	Y	N
176	S_HAN	N	N	Y	N
177	S_HAN	N	N	Y	N
178	S_HAN	N	N	Y	N
179	S_HAN	N	N	Y	N
180	S_HAN	N	N	Y	N
181	S_HAN	N	N	A.H.	N
182	S_HAN	N	N	Y	N
183	S_HAN	N	N	Y	N
184	S_HAN	N	N	Y	N
185	S_HAN	N	N	Y	N
186	S_HAN	N	N	Y	N
187	S_HAN	N	N	Y	N
188	S_HAN	N	T	Y	N
189	S_HAN	N	N	Y	N
190	S_HAN	N	N	N	H
191	S_HAN	N	N	Y	N
192	S_HAN	N	N	Y	N
193	S_HAN	N	N	Y	N
194	S_HAN	N	N	Y	N
195	S_HAN	N	N	Y	N
196	S_HAN	N	N	Y	N
197	S_HAN	N	N	Y	N
198	S_HAN	N	N	Y	N
199	S_HAN	N	N	Y	N
200	S_HAN	N	N	Y	N

Respondent No.	Location	Role of desludging	Septage to where	Septage to compost	Concern
201	U_DAN	N	T	D.K.	N
202	U_DAN	N	N	Y	N
203	U_DAN	N	N	Y	N
204	U_DAN	N	N	Y	N
205	U_DAN	N	N	Y	N
206	U_DAN	N	T	Y	N
207	U_DAN	N	N	Y	N
208	U_DAN	N	T	Y	N
209	U_DAN	N	N	N	N
210	U_DAN	N	N	Y	N
211	U_DAN	N	N	Y	N
212	U_DAN	N	T	Y	N
213	U_DAN	N	N	Y	N
214	U_DAN	N	N	Y	N
215	U_DAN	N	T	Y	N
216	U_DAN	N	N	D.K.	N
217	U_DAN	N	N	Y	N
218	U_DAN	N	N	Y	N
219	U_DAN	N	N	N	N
220	U_DAN	N	N	Y	N
221	U_DAN	N	N	Y	N
222	U_DAN	N	N	Y	N
223	U_DAN	N	T	Y	N
224	U_DAN	N	N	Y	N
225	U_DAN	N	N	Y	N
226	U_DAN	N	N	Y	N
227	U_DAN	N	N	Y	N
228	U_DAN	N	N	Y	N
229	U_DAN	N	T	Y	N
230	U_DAN	N	N	Y	N
231	U_DAN	N	T	Y	N
232	U_DAN	N	N	Y	N
233	U_DAN	N	N	Y	N
234	U_DAN	N	T	Y	N
235	U_DAN	N	N	Y	N
236	U_DAN	N	T	Y	N